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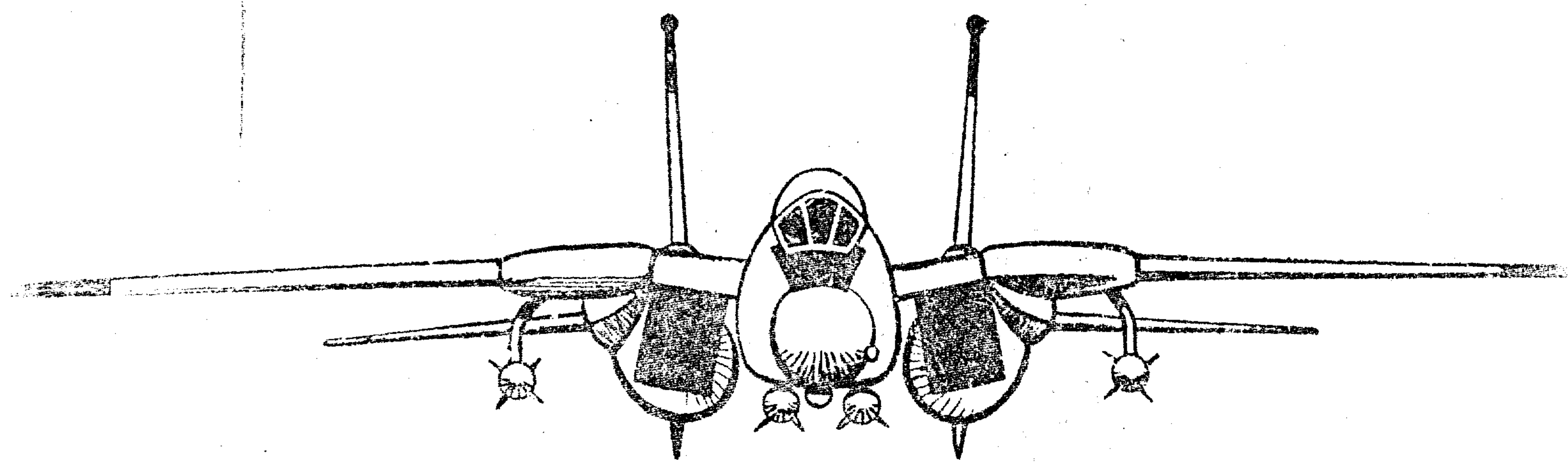

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AIRCRAFT/STORES COMPATIBILITY SYMPOSIUM PROCEEDINGS

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B-1 30-INCH EJECTOR (U)

(Article Unclassified)

by

Paul F. Peterson
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B-1 Division
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Los Angeles, California 90009

ABSTRACT. (U) A new, lightweight, high-performance, 30-inch ejector has been developed for the B-1. While its primary use is for nuclear weapon carriage on rotary launchers, it is also used to carry conventional stores. Two large Navy-developed cartridges provide high energy over a long period of time without imposing severe peak forces on the ejected store. A gravity backup release system is provided, together with nuclear safety and ground safety locking systems.

High peak gas pressures such as 10,000 to 15,000 psi are used in the new ejector. This promotes unusually clean burning and, therefore, the ejector requires little maintenance. The use of the ejector on the B-1 is briefly described and the constraints driving the design are outlined. Development status of the new ejector and schedules for future tests are described.

LIST OF FIGURES

Figure

THE B-1 30-INCH EJECTOR

A new long-stroke, lightweight, high-performance ejector has been designed for suspension of large weapons aboard the B-1. First, a look at some of the constraints surrounding the design of the ejector. The B-1 (figure 1) shows AGM-69 missiles in the forward bay, nuclear bombs in the center bay, and decoy or other type missiles in the aft weapons bay. While these stores are all of nuclear configuration, the ejector is also designed to carry large conventional weapons such as MK84 and other weapons using 30-inch suspension. The ejector has been designed essentially around the requirements for the AGM-69 missile, which weighs 2,245 pounds and is 168 inches long. The weapon mounts to a rotary launcher as shown in figure 2, and consists of a cluster of eight weapons mounted to a tubular structure. Sway bracing is done on the launcher, rather than the ejector. The launcher is of a clip-in type with rotational loads taken at the forward end, and fore and aft loads taken at the aft end. An electrohydraulic drive mechanism rotates the launcher so that weapons may be launched at short intervals. In order to create an efficient structure for the rotary launcher, the ejector pistons and cylinders are built into gas manifold housings. These housings are then inserted into the launcher through holes, as shown in figure 3. The mechanism for the ejector then is of very short height, which allows the maximum tube diameter and greatest efficiency in tubular structure.

Figure 4 is a photograph of one ejector shown complete and one with the side plate and both pistons removed showing the linkage. The internal details of the ejector are shown in figure 5. The hooks are attached to load-reducing toggles which reduce the load sufficiently so that two long rods connected to a central bellcrank carry the load into the inner mechanism of the trigger box. The pistons are spring loaded against the store, but are not retractable after ejection. The safety latches and the releases for the trigger are all contained in a dust-free box. A nuclear safety solenoid is provided and, of course, is locked out when conventional weapons are carried. Gravity drop solenoid is provided as a backup mode of operation to the normally gas-operated system, which employs two MK107 cartridges to eject weapons. The MK107 is a new Navy cartridge already in fleet usage on other aircraft. Also shown in figure 5 are the removable cylinder, piston, and probe which comprise the basic ejection system.

Figure 6 outlines the requirements for rise time and peak thrust, and shows a typical performance curve generated by the B-1 ejector. The ejector thrust is limited by 5-millisecond minimum rise time to a

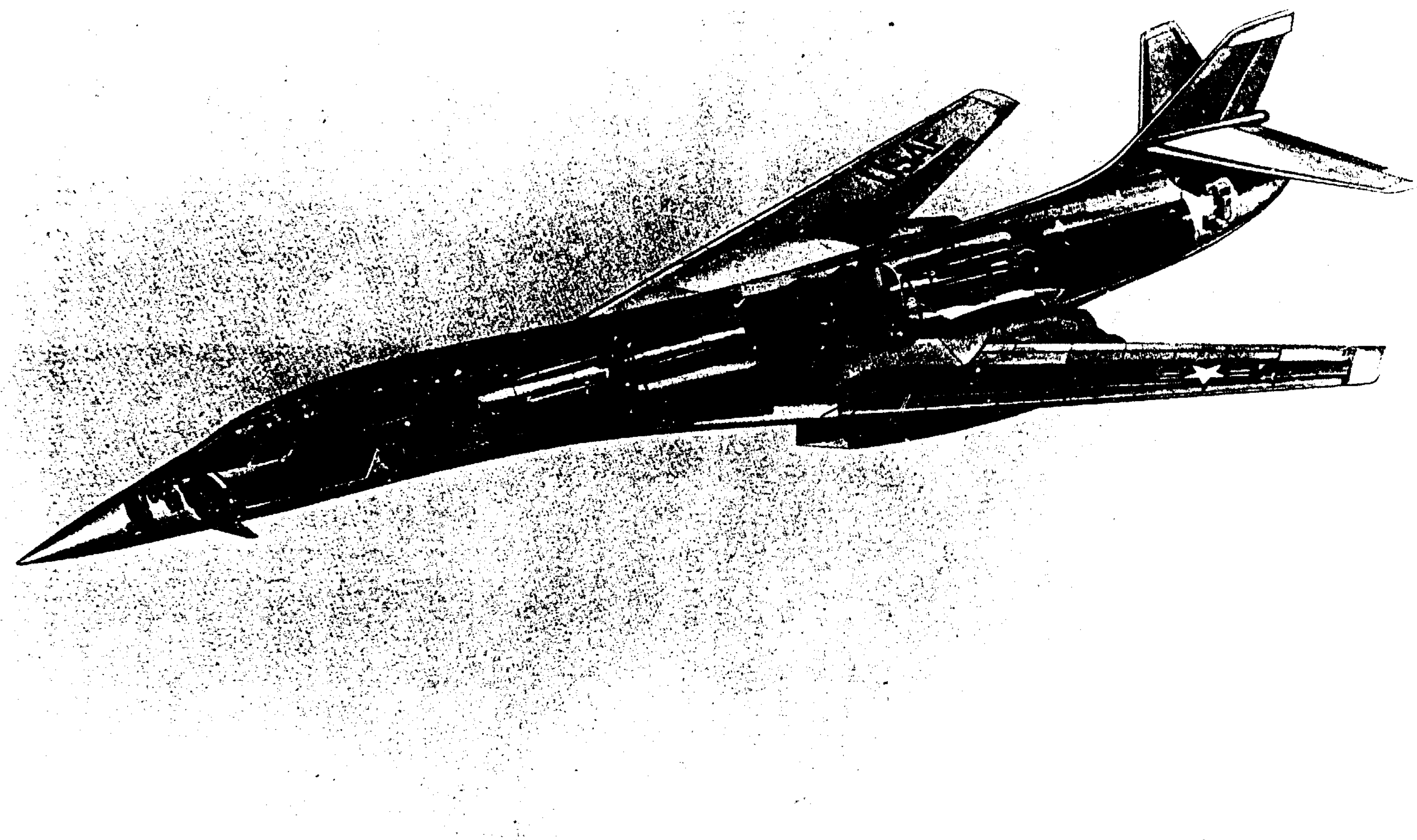


Figure 1. B-1 Aircraft - Inboard Arrangement

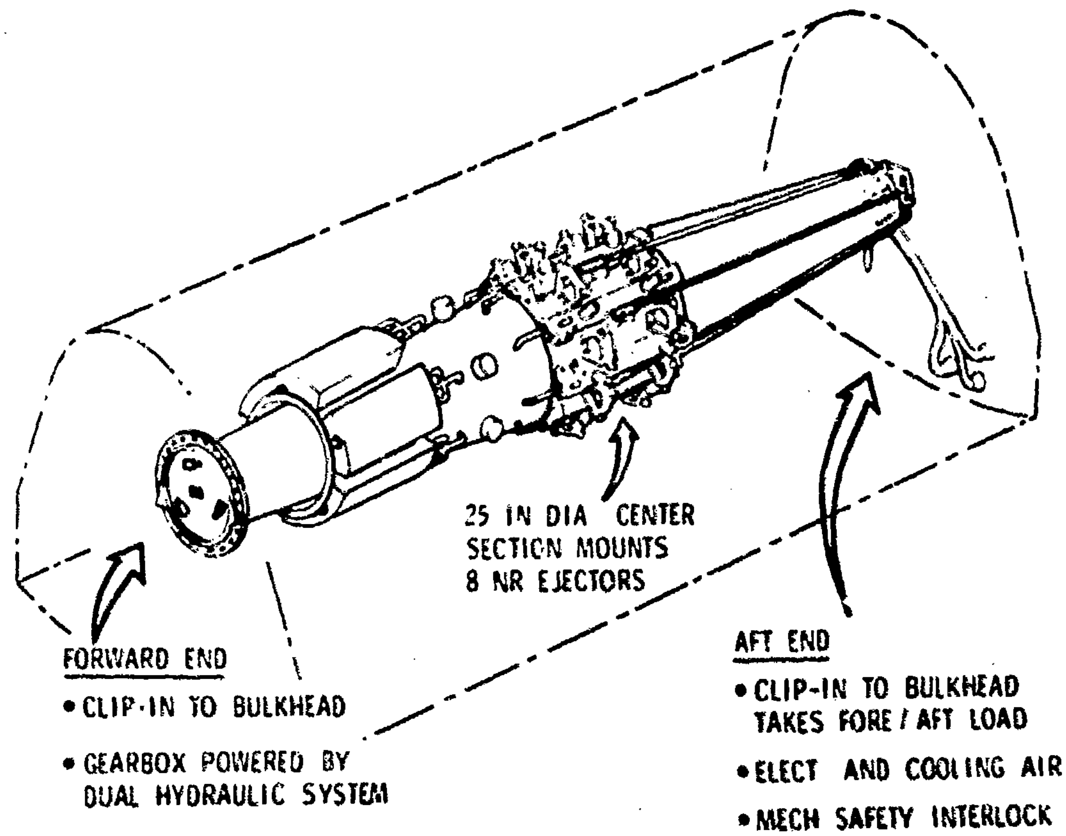


Figure 2. AGM-69 Rotary Launcher

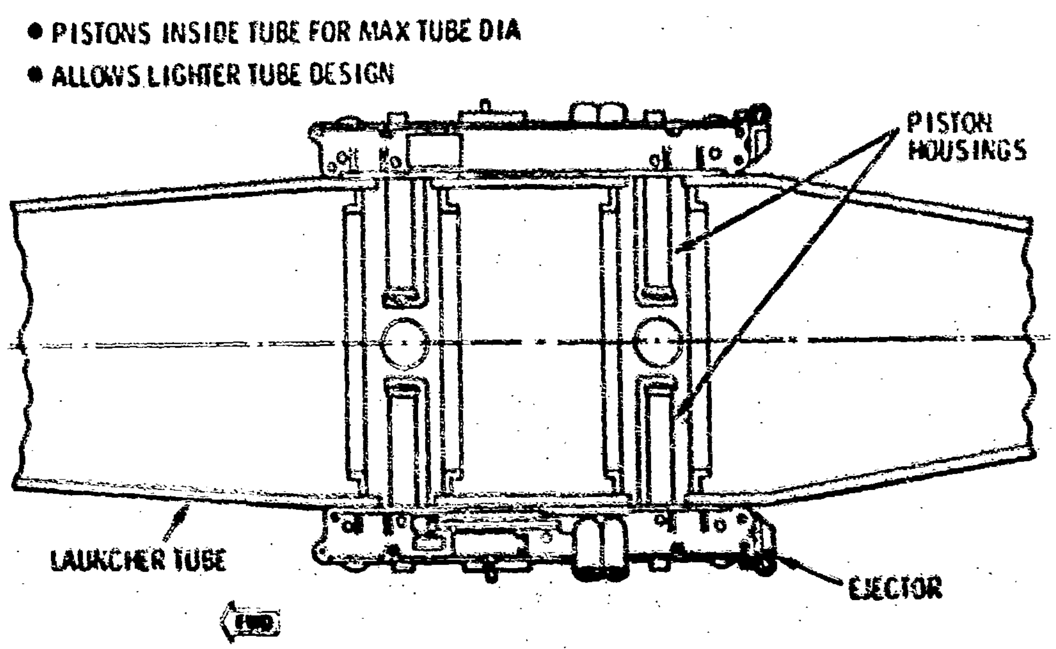


Figure 3. Launcher and Ejector Interface

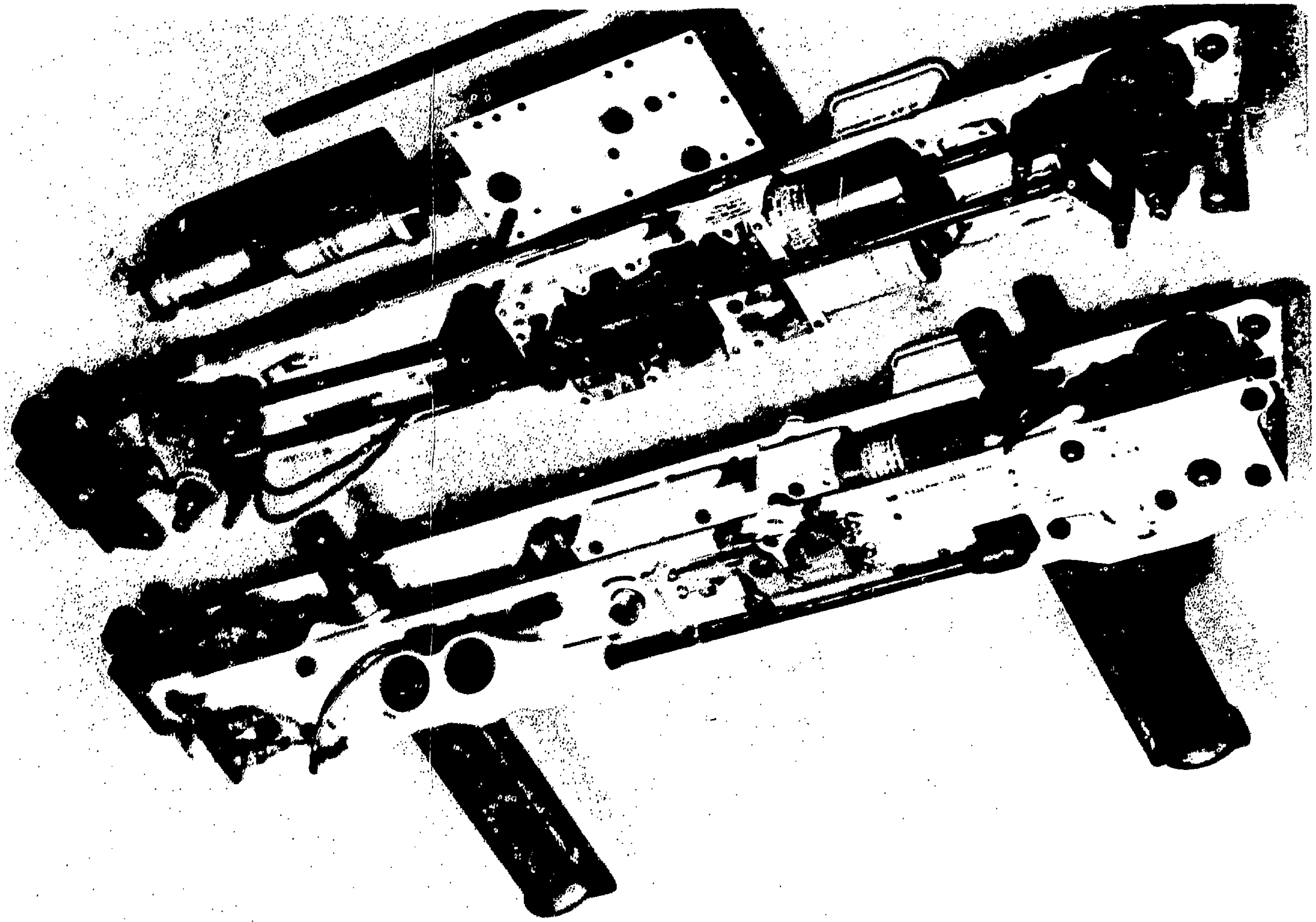
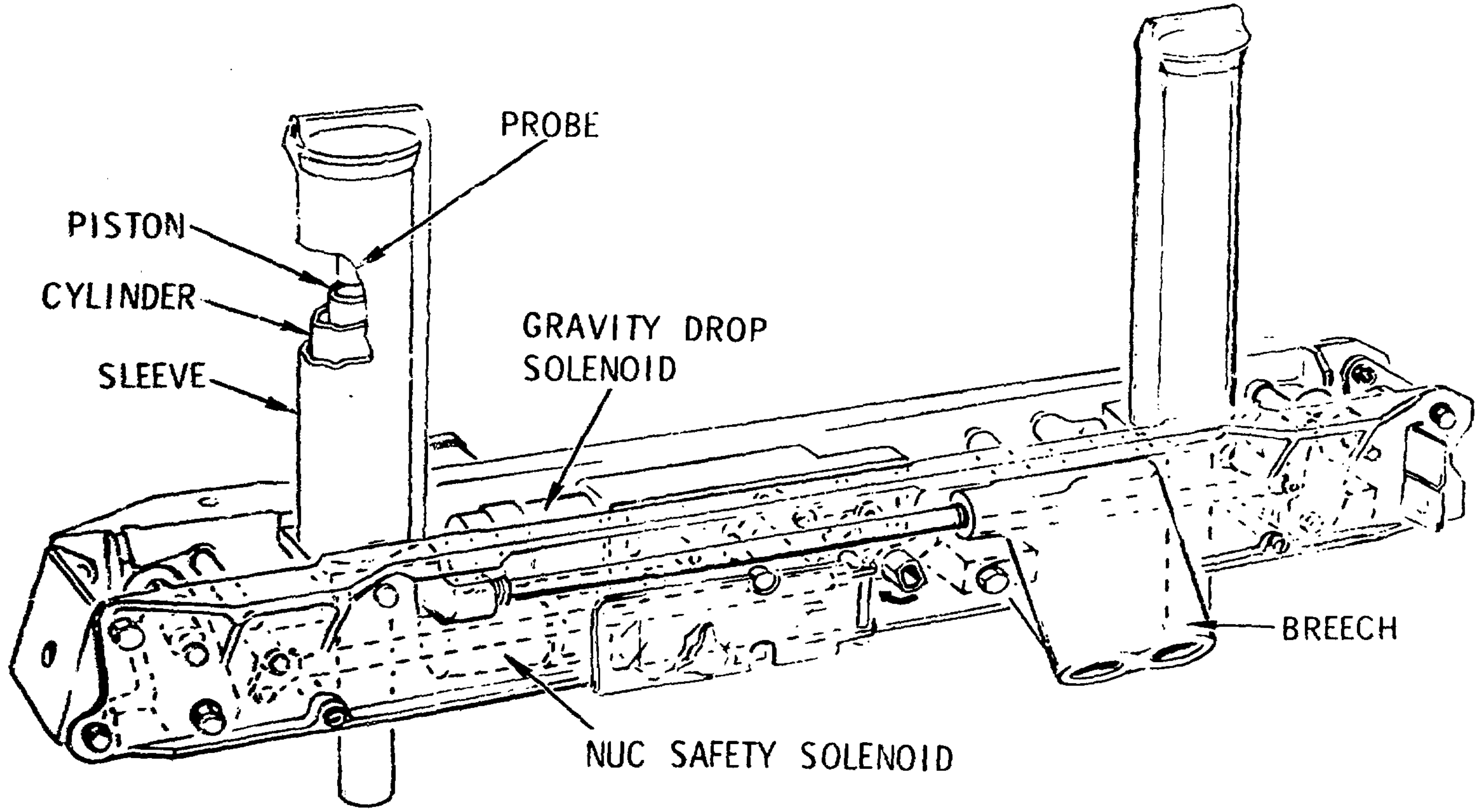
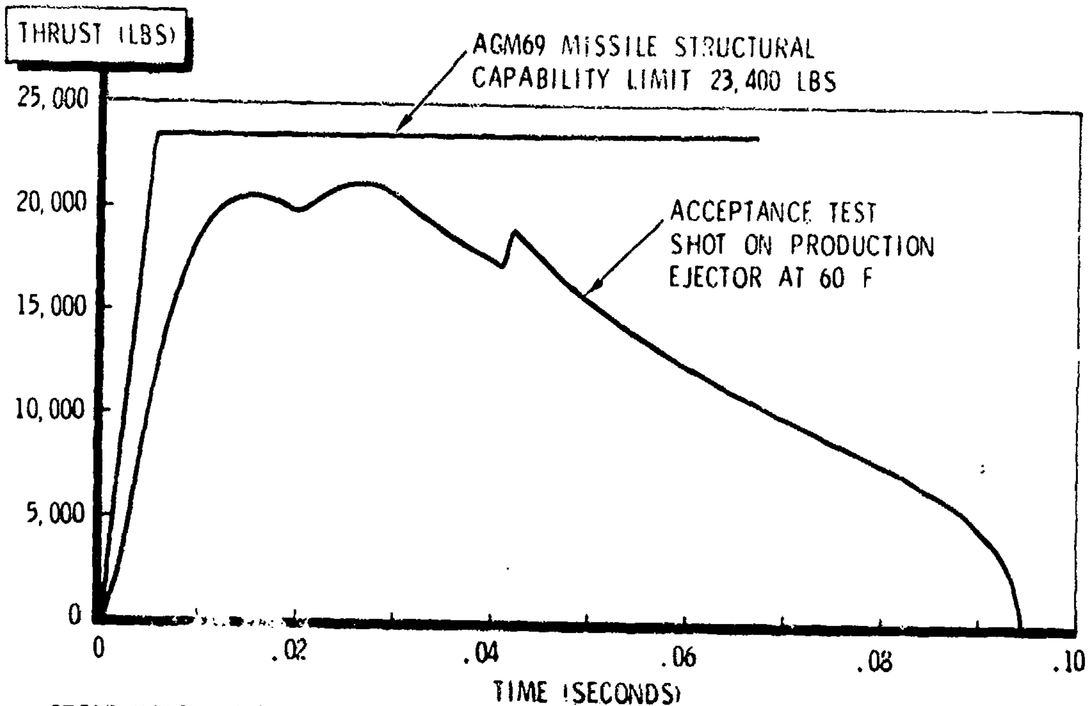


Figure 1. [illegible] 30-Inch Ejector Rack



- WEIGHT - 54 LBS
- PROVIDES 20 FPS WITH 10 G PEAK FORCE
- GRAVITY DROP BACK-UP CAPABILITY
- USES MK 107 CARTRIDGES NOW IN FLEET USAGE
- MEETS EMR & EMP REQUIREMENTS

Figure 5. B-1 30-Inch Ejector



- STORE WEIGHT 2,245 LBS
- ACCELERATION APPLIED 9.5 G'S
- SEPARATION VELOCITY 20.9 FPS

Figure 6. 30-Inch Ejector Requirements and Typical Performance

peak of 23,400 pounds, which is the maximum structural capability of the SRAM missile. The curve shown in figure 6 was fired at approximately 60° F and was one of the acceptance test shots on a production ejector. The acceleration applied was 9.5 g, and a separation velocity of 20.9 feet per second was produced. It may be seen from this performance curve that an unusual condition is created in the ejector where a relatively long-peak flat-topped thrust time curve has been developed. This is probably the most unique feature of the B-1 ejector. How this is done is shown in figure 7, where at the beginning of the stroke, gas enters the inlet and is ducted through a stepped probe. This probe is configured so that a very small amount of clearance is available between the probe and the interior of the piston at the beginning of the stroke. Therefore, high-pressure gas from the gas inlet fills the cavity in the piston and allows a very small leakage to occur between the probe and the piston. This creates a low-pressure gas area on top of the piston head. As the piston continues to stroke during ejection, small additional areas are uncovered on the probe in a series of steps which allows more and more gas to leak to the top side of the piston. As the piston leaves the probe, the ejector then functions like most other ejectors, where adiabatic expansion of the gases continues to push the store away. Figure 8 shows how the thrust time curve compares with the pressure time curve. It can be seen that 80 percent of the peak pressure is maintained for only 12 milliseconds. However, because of the mechanical orificing of gases

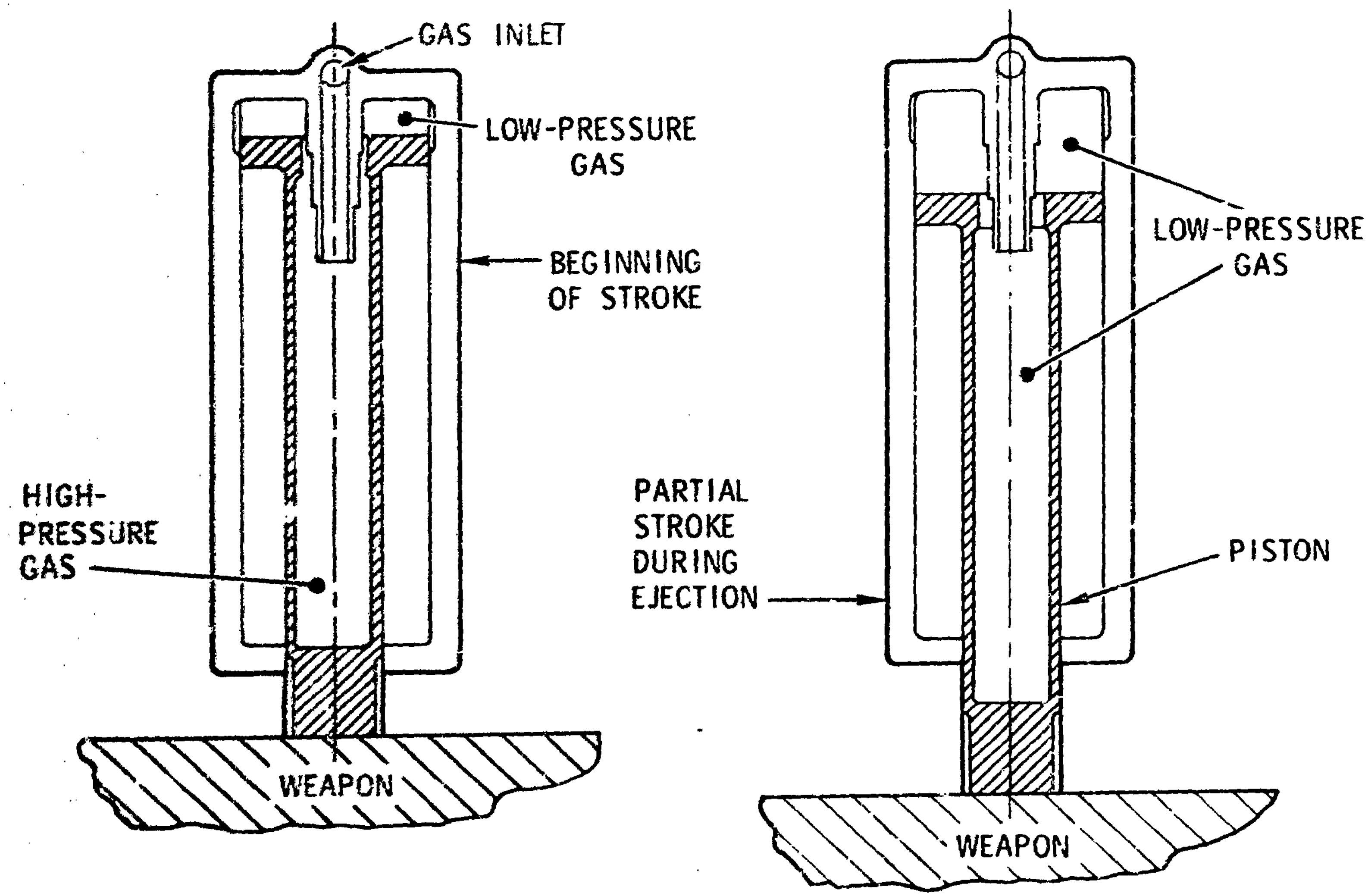


Figure 7. Ejector Gas System Operation

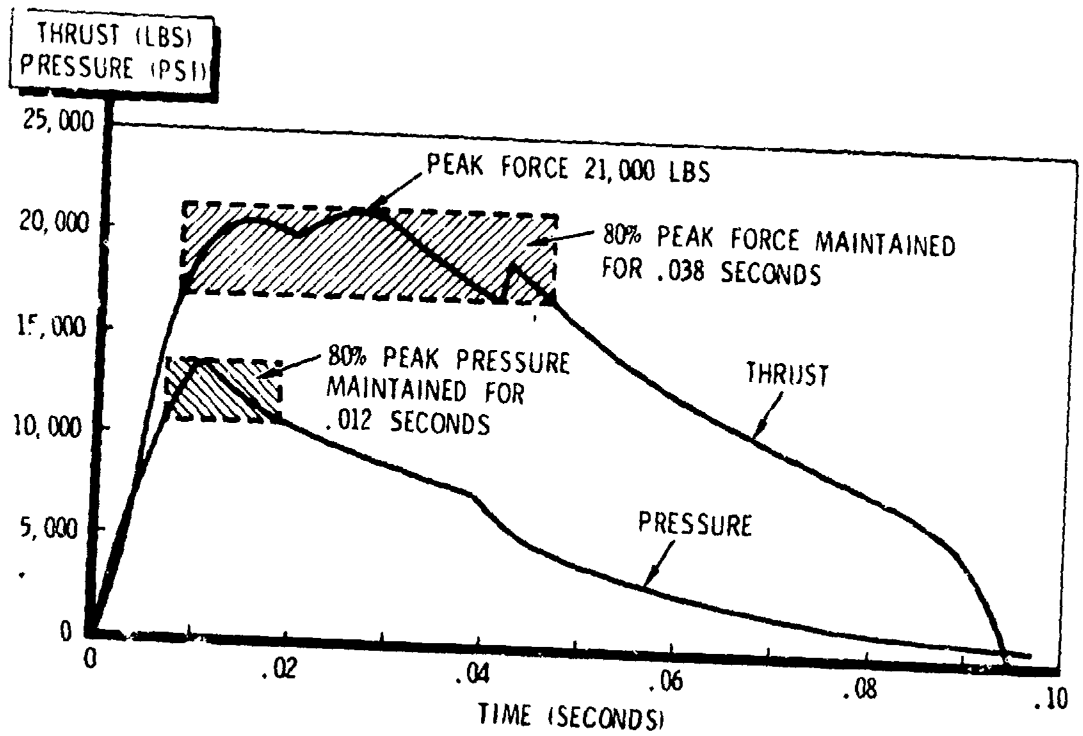


Figure 8. Total Thrust Versus Breech Pressure

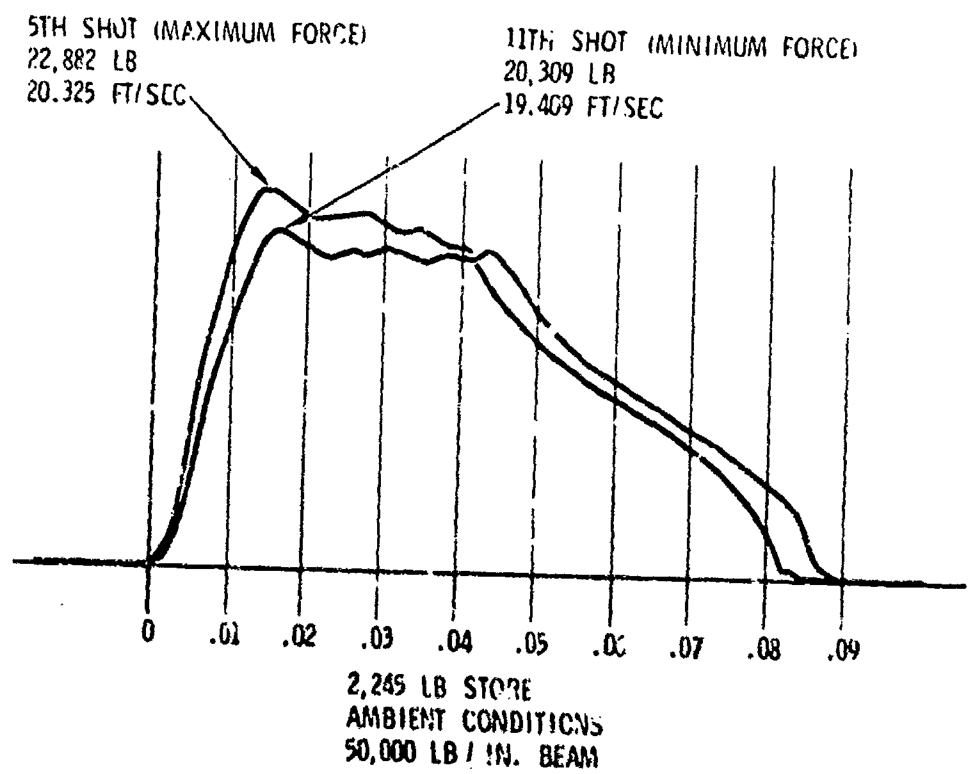


Figure 9. Force-Time Variations of 30-Inch Ejector Over 25-Shot No-Clean Cycle

around the probe, 80 percent of the peak force is maintained for 58 milliseconds. Therefore, high ejection velocity can be provided with relatively small peak forces. A computer program was used to develop the ejector and probe configuration before testing to determine final step shaping.

A series of no-cleaning shots was run over a period of about 3 weeks. (See figure 9.) The maximum force occurred on the fifth shot, and the minimum force occurred on the 11th shot. All of the other shots in the 25-shot cycle were within these two limits. It is apparent from figure 9 that very clean burning exists in the B-1 ejector. It is felt that this clean burning is promoted by the high breech pressures of over 13,000 psi, and by the use of a propellant screen just downstream of the ejector cartridges. Figure 10 shows variations of the ejector's performance relative to temperature changes. Only a very few firings were done at varying temperatures, and the sample shown is representative of only these few firings. It can be seen, however, that there is little change in peak loads and also little change in velocity produced. The most pronounced effect appears to be rise time, which changes significantly with temperature variations.

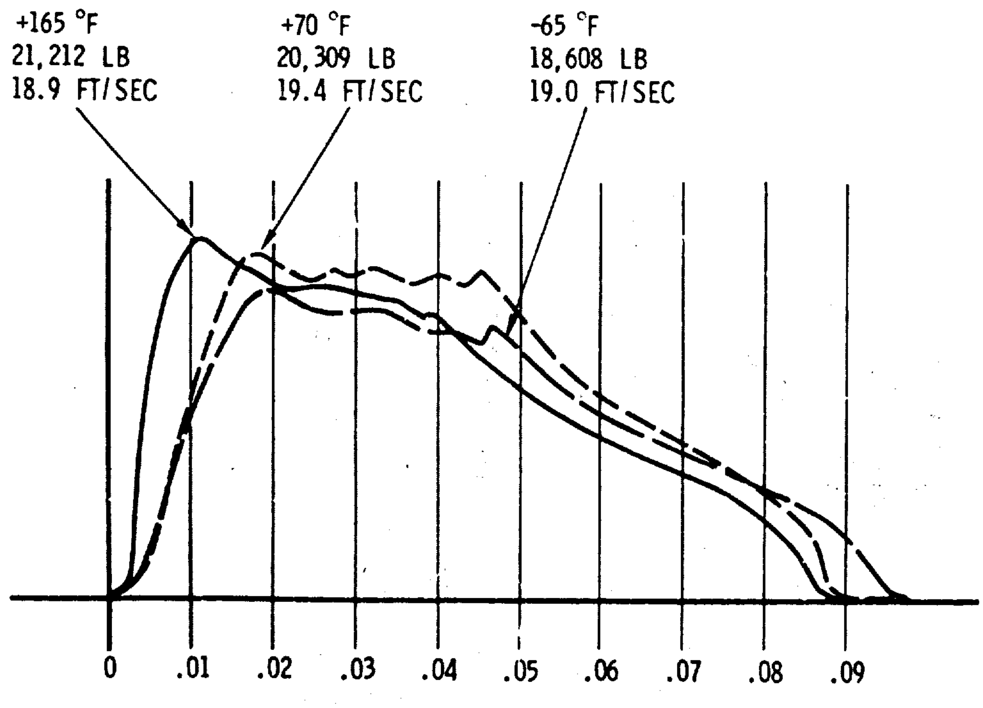


Figure 10. 30-Inch Ejector Performance With Temperature Variations

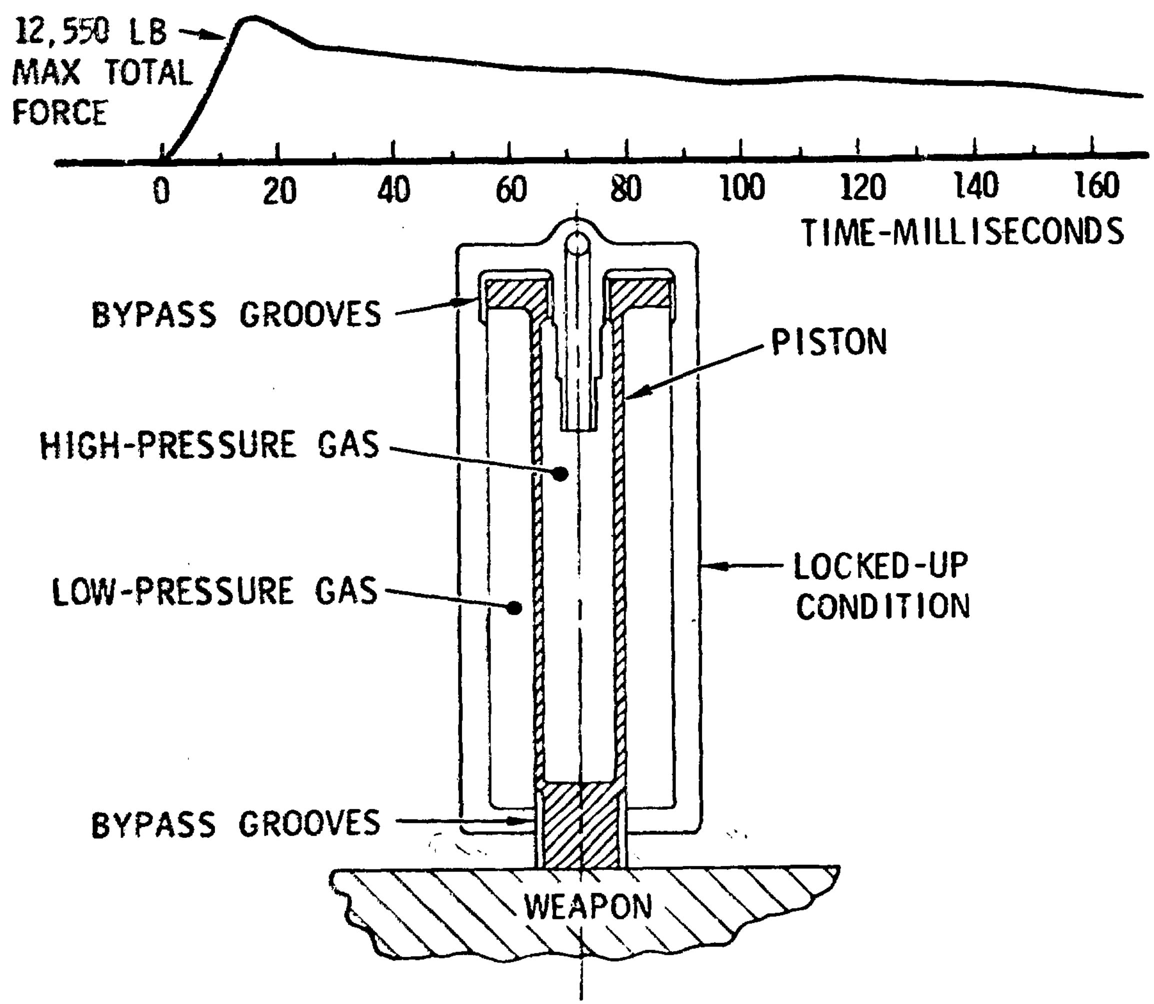


Figure 11. Ejector Locked-Up Gas System Performance

Another feature of the B-1 ejector is the low peak force generated by a locked up shot. This phenomenon is shown in figure 11, where the curve shows maximum force of only about half that generated during the ejection cycle. This is accomplished by the use of small bypass grooves at the top of the cylinder and around the bottom of the piston. This allows the high-pressure gas to bleed around the probe, over the top of the piston, through the bypass grooves, down through the main portion of the cylinder, and out the bypass grooves at the bottom of the cylinder. In the normal ejection cycle these grooves quickly seal up with piston motion and have no effect on normal ejection of the store.

The thrust and velocity capabilities of the B-1 ejector are shown in figure 12 relative to store weight. As store weight decreases, peak thrust also decreases and, of course, velocity increases. These curves were taken from Rockwell's computer program and have been validated by ejection of the B61 store, which weighs 700 pounds and achieved a velocity of 37 feet per second.

Methods to create pitch on the store have been evaluated in the form of orificing, and also in the form of destroking the pistons. The orifice technique unfortunately increased breech pressure to unmanageable levels for the MK107 cartridge. Therefore, a spool technique was applied as shown in figure 13, where a simple aluminum tubular member is installed beneath the head of the piston. The performance of the stroke-limiting technique is shown in figure 14, where the pitch rate in degrees per second is plotted against piston stroke in inches. This information was created relative to the AGM-69 missile, which has a pitch moment of inertia of 870-slug ft.^{2}. Associated with any pitching of the store, there is an attendant loss in store ejection velocity, which is plotted in figure 15.

The MK107 MOD 5 ejector cartridge is shown in figure 16. It was selected basically because of the propellant quantity, the EMP safe bridge wire configuration, the expected clean-burning characteristics, and the sympathetic ignition features. A significant feature of the cartridge is shown at the downstream end, where an aluminum closure is bonded to a simple propellant trap and contains one gram of bullseye powder. Experience in sympathetic ignition tests has shown that as the bullseye ignites, a flash is carried across to the other chamber, igniting the bullseye in the second cartridge and thus producing sympathetic ignisympathetic ignition characteristics where the ejector performance curves appear identical to those when both cartridges are ignited. The MK107 is also used for Phoenix and fuel tank ejection on the F14. While the MK107 is considered an excellent performing cartridge, it has had its early problems. Figure 17 shows a cutaway of the cartridge as it should

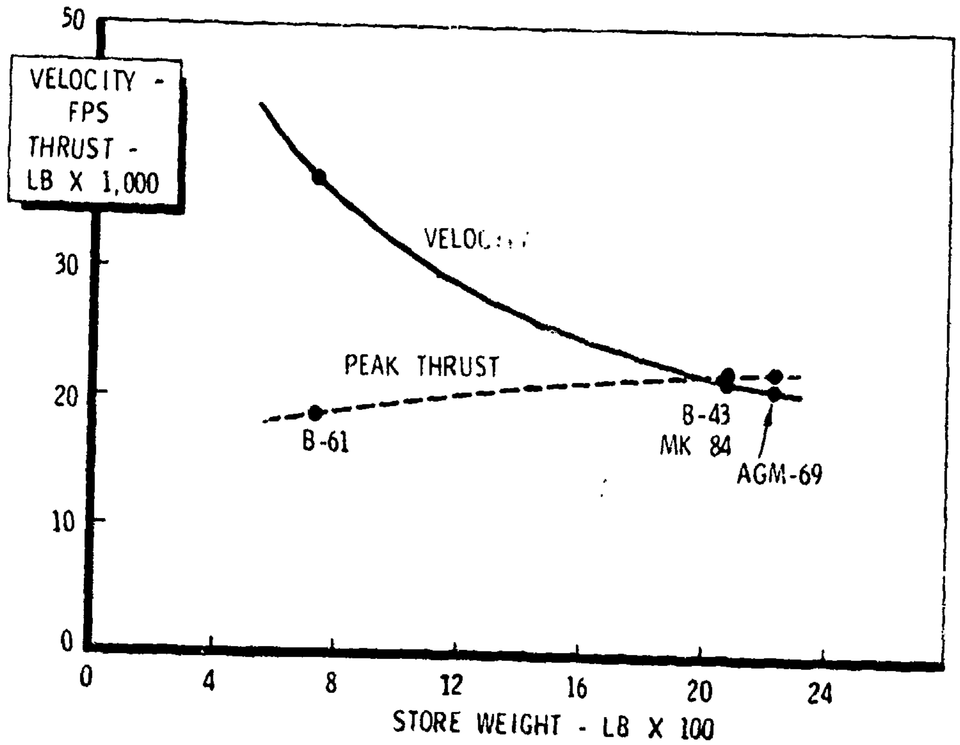


Figure 12. Thrust and Velocity Versus Store Weight

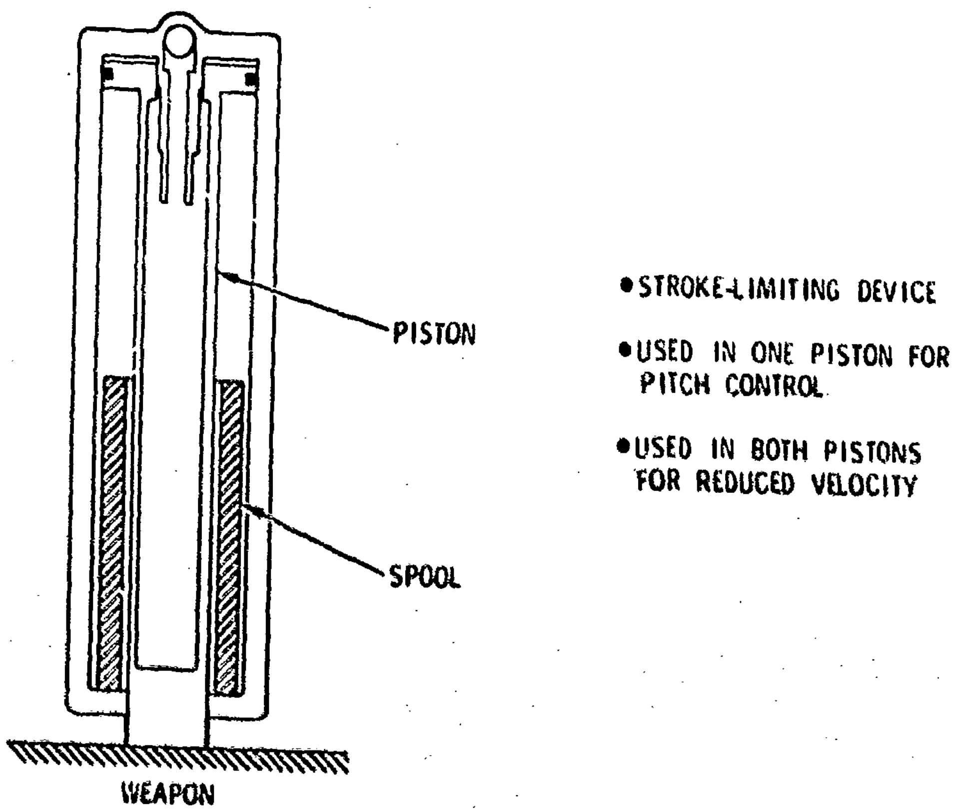


Figure 13. Pitch and Velocity Control

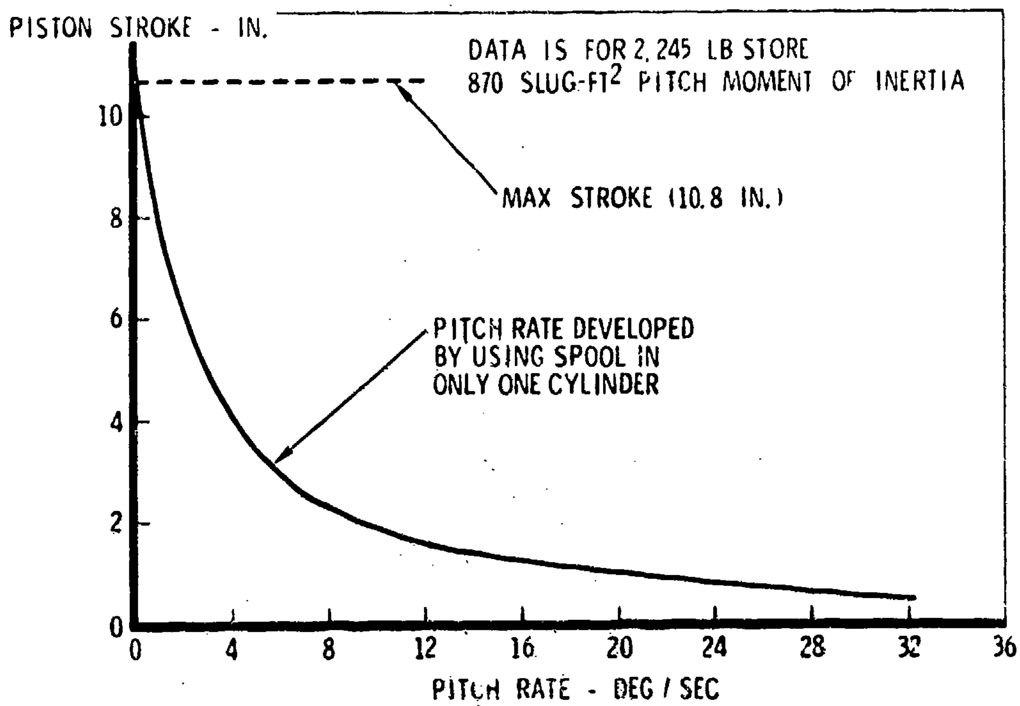


Figure 14. Piston Stroke Versus Pitch Rate

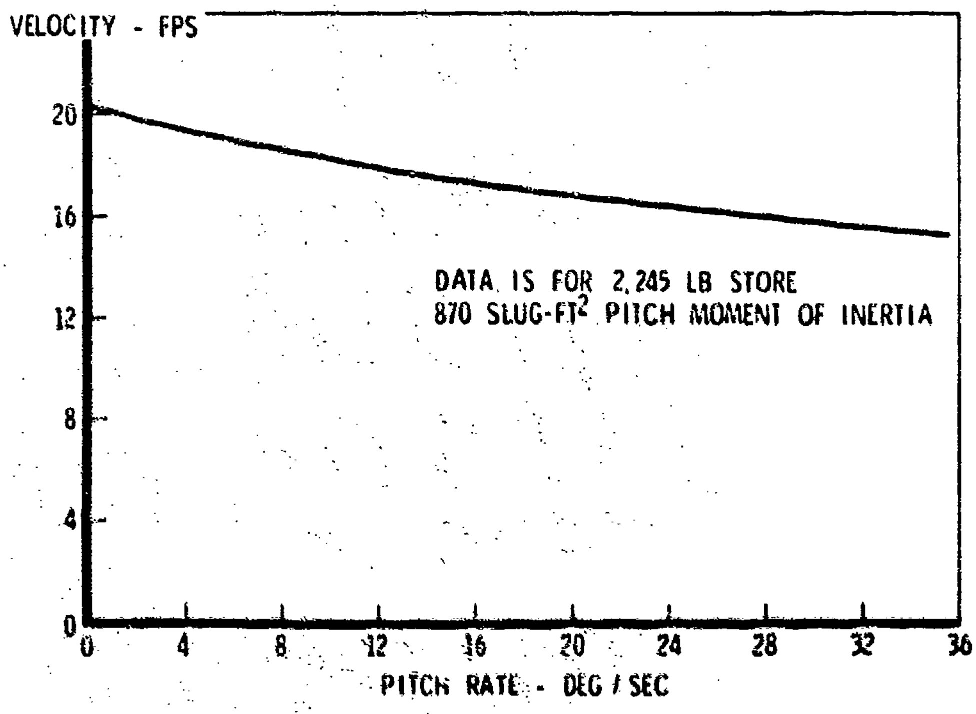
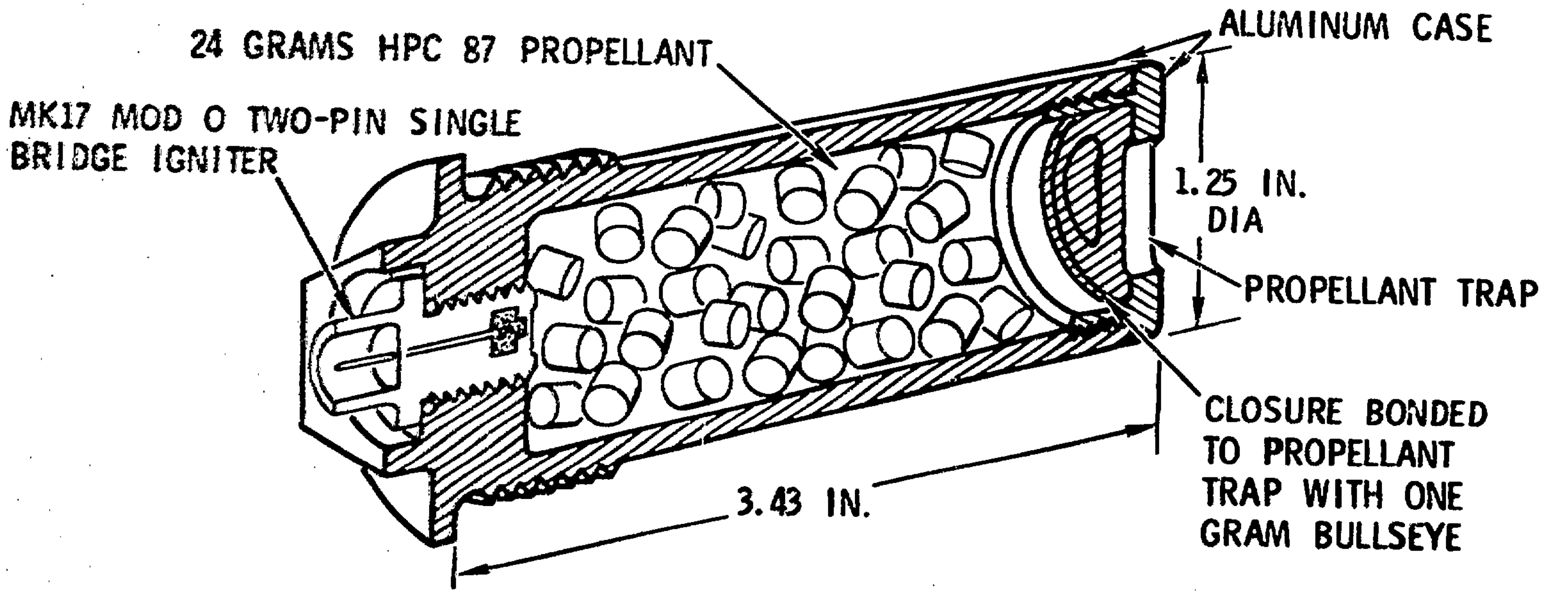


Figure 15. Velocity of CG Versus Pitch Rate



- 25 GRAMS TOTAL PROPELLANT CHARGE
- EXHIBITS EXCELLENT SYMPATHETIC IGNITION CHARACTERISTICS
- WEIGHT 0.37 LBS - COST APPROX $30
- IN PRODUCTION AT INDIAN HEAD
- USED FOR PHOENIX & F-14 FUEL TANK EJECTION

Figure 16. MK107 Mod-5 Ejector Cartridge

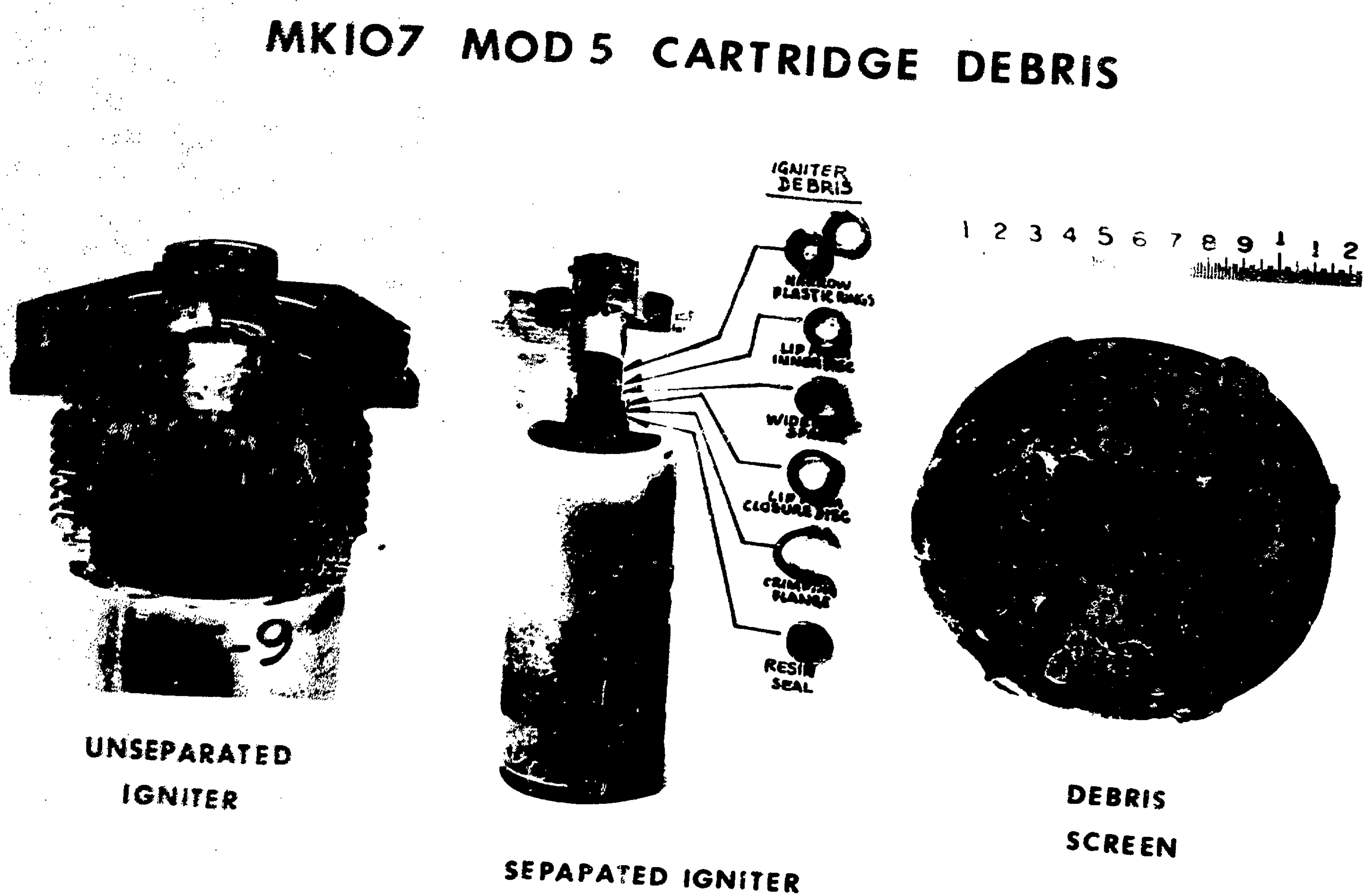


Figure 17. MK107 Mod-5 Cartridge Debris

appear after firing. Also shown is another cartridge in which igniter debris escapes occasionally during the firing. It can be seen that several plastic and metal rings are expelled from the cartridge and could go downstream through the ejector. For this reason, a debris screen was developed, also shown on figure 17, which does not restrict gas flow, but does contain all of the debris. It is felt that this screen aids in the burning process.

The controls for the 30-inch ejector are all on the exterior of the rack, and the basic manual capability is shown in figure 18. This figure shows the ejector configuration for carriage with nuclear stores. A lucite plate is used to cover the two controls necessary to be functioned for ground release. This lucite plate is safety wired in place so that several conscious actions must be taken to manually release the store. The plate is reversible and, as shown in figure 19, is configured for conventional stores. In this mode, a small tab on the lucite plate holds the nuclear safety lock in the unlocked condition. When a store is to be released on the ground, the safety wire must be removed. The plate is then swung out away from the controls, which then allows the nuclear safety lock to go back into the locked position. To release the store, the nuclear safety lock must be moved to the unlock position and held there while the rack lock is moved to the release position.

Some of the details of the trigger mechanism are shown in figure 20. The gravity release solenoid is shown schematically and can be used to drive the release linkage. Normally, the gas-operated power piston is used to drive the linkage, from the beginning of motion, all the way through to full opening of the hooks. The heart of the mechanism is the trigger, which keeps the final-stage toggle roller in place. The full-travel position of the mechanism is shown in figure 21, where it can be seen that as the trigger is pulled up, the linkage containing the roller is allowed to collapse, while continued force on the power piston provides force to open the linkage throughout is full travel. Another feature of the trigger mechanism is shown in figure 22, where the masses of the solenoid slugs are counterbalanced by weights to preclude motion of the solenoid slugs during vibration and shock. A linkage counterweight is also provided so that the remaining elementsof the linkage, which could possibly cause release of the store, are fully-balanced.

One of the important features of the 30-inch ejector is the hook configuration shown in figure 23. A basic problem existed in the design of the hook due to the extreme hardness of the AGM-69 missile clevis. The underside of the clevis is shot-peened material at approximately 250,000 psi hardness. The challenge here was to develop an even harder hook. Several materials were investigated, and the final choice

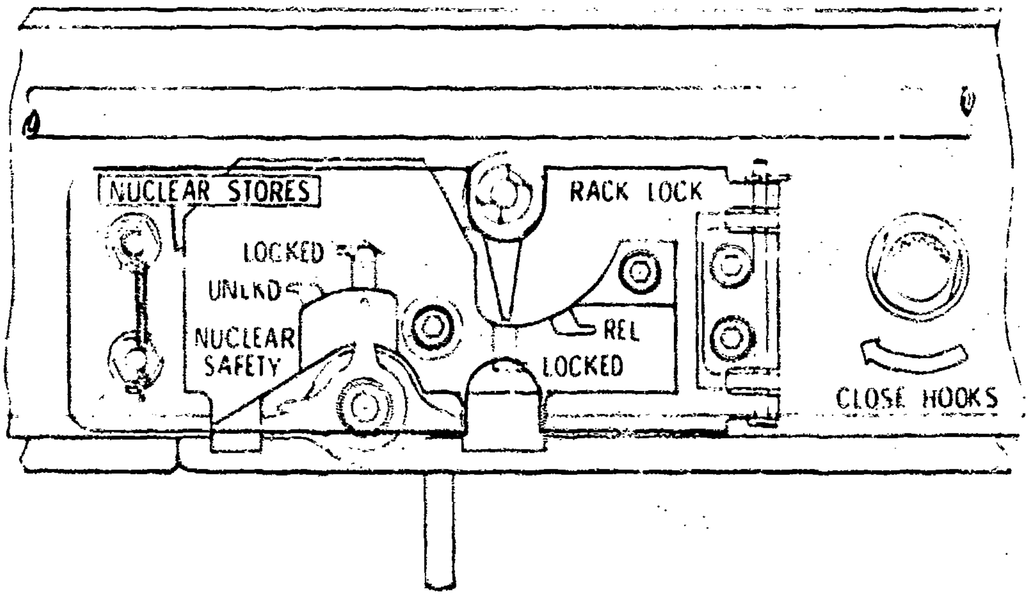


Figure 18. 30-Inch Ejector Controls - Nuclear

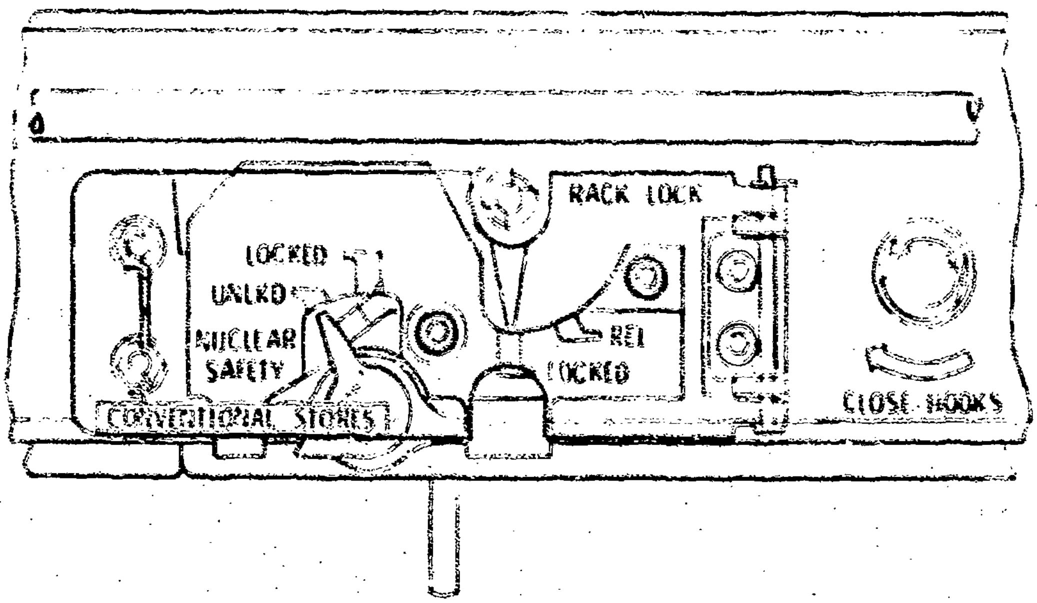


Figure 19. 30-Inch Ejector Controls - Conventional

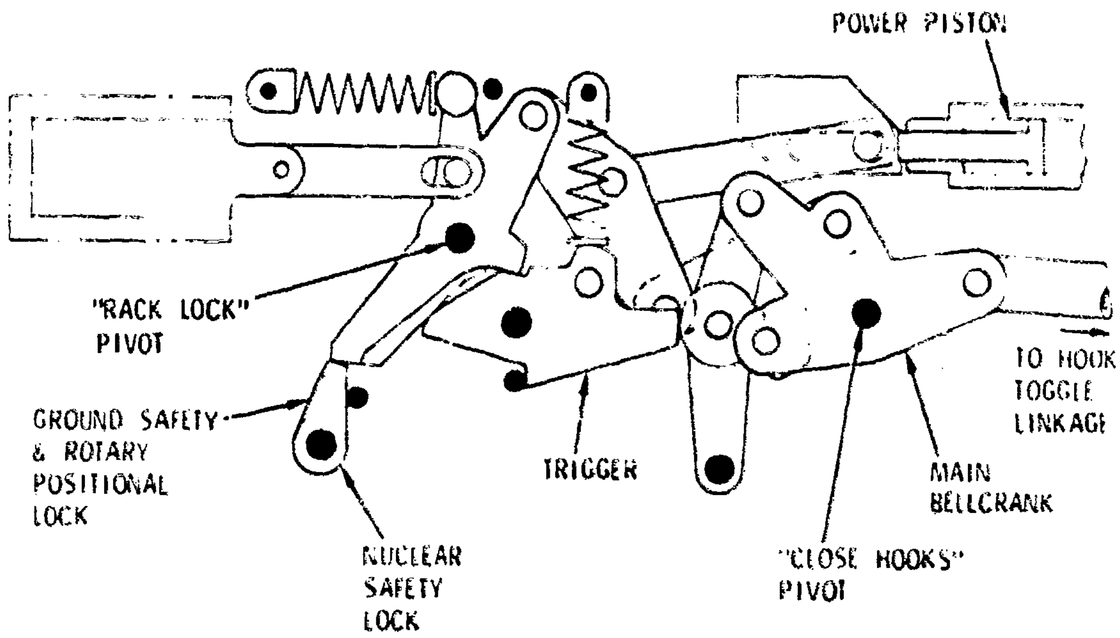


Figure 20. 30-Inch Ejector-Trigger Mechanism - Locked

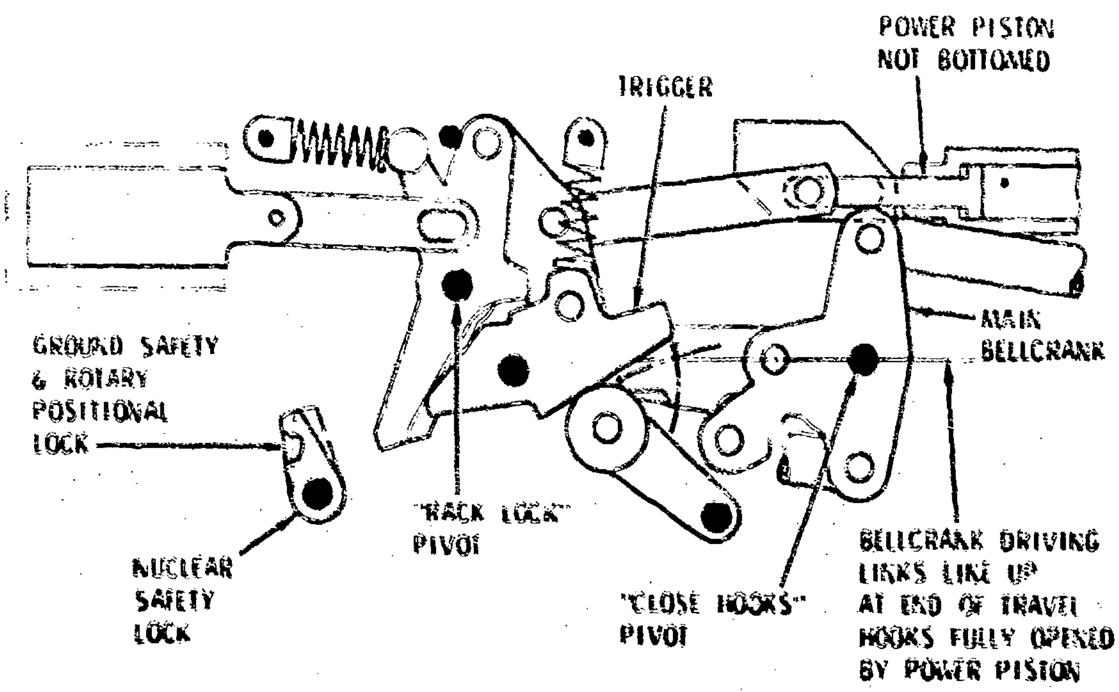


Figure 21. 30-Inch Ejector-Trigger Mechanism - Unlocked

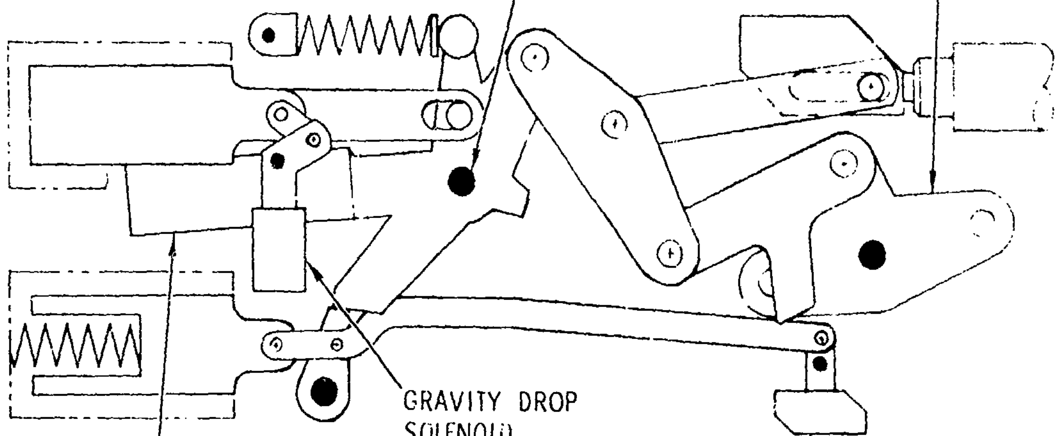


Figure 22. 30-Inch Ejector-Trigger Mechanism - Counterbalanced

- PROBLEM - AGM-69 CLEVIS IS SHOT PEENED PH13-8Mo AT RC50 (250,000 PSI)
- HARDER HOOK SURFACE IS NEEDED FOR POSITIVE RELEASE
- MATERIALS INVESTIGATED
    - 9310 CARBURIZED & CHROMED
    - PH13-8Mo WITH 0.050 STELLITE SURFACE
    - H-11 AT RC 52-55 & CHROMED (RC 64)
    - PH13-8Mo NITRIDED
- TESTS WERE RUN TO DETERMINE COEFFICIENT OF FRICTION & CHOOSE MATERIAL
- FINAL CHOICE - H-11 CHROMED & GROUND TO 16 MICRO INCHES

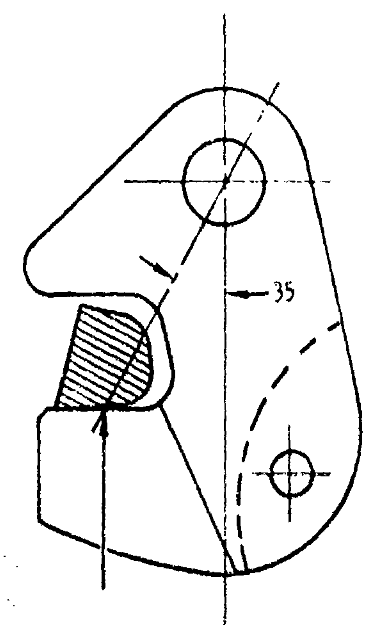


Figure 23. 30 Inch Ejector Hook

was H11 alloy steel, chromed and ground. This configuration survived all of the vibration and shock tests under load with no visible deformation.

Maintenance of the B-1 ejector is very simple. While the ejector is not easy to assemble, complete disassembly is basically unnecessary. For normal maintenance, the piston, probe, and cylinder can be removed as a unit for cleaning without other disassembly or removal of the ejector from the air vehicle. All of the trigger parts are housed in a dust-free box, and since the propellant screen eliminates downstream debris, infrequent cleaning will be all that is necessary. There are no O-rings or other AGE sensitive parts in the B-1 ejector. All prequalification and a significant part of formal qualification tests are complete. Rockwell's ejector test facility is shown in figure 24, where a B61 bomb is mounted to the ejector. The test stand is fully instrumented for several pressure, thrust, and motion parameters. The development summary of tests is shown in table I, and includes sympathetic, locked shut, and hot and cold firings. The ejector is shown in figure 25 in outline configuration for those who might be interested in its usage.

Suggestions for ejector designers - based on the development discussed - include the following practical factors:

- Do use high pressures to promote clean burning.
- Don't use O-rings or other AGE-sensitive items.
- Get as much area under work curve as possible.
- Use superhard hook faces.
- Design for high hook opening moments.
- Use counterweights with solenoids.
- Use propellant screens.

Store designers should show a little compassion for ejector designers by using softer materials in their special lugs, or at least not harder materials than those shown in MIL-A-8591. After all, the store is the throwaway item, not the rack. The rack hook must be built so that it does not deform; otherwise, the rack cannot function properly.

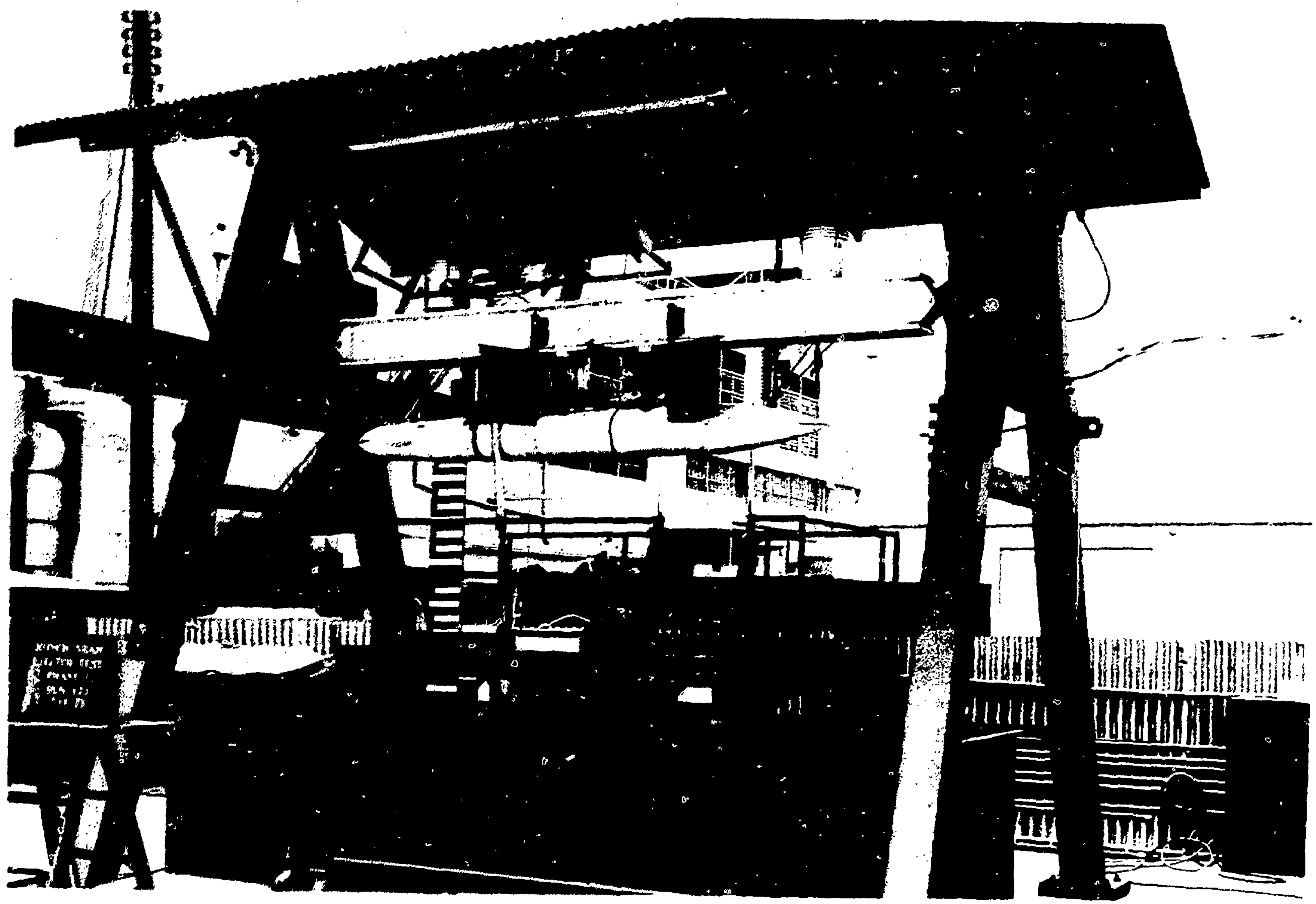


Figure 24. Test Facility

Table I

DEVELOPMENT TEST SUMMARY (30-INCH EJECTOR)

Test	Number
Ambient firing tests with 2,245 lb store	136
•Normal (two-cartridge ignition)	136
•Sympathetic (one-cartridge ignition)	6
•Locked shut	2
+165° F firing tests	3
-65° F cold-warm-cold tests	12
Ambient gravity drops	5
+165° F gravity drops	1
-65° F cold-warm-cold drops	4
Ambient firing tests with 700 lb store	
Total	172

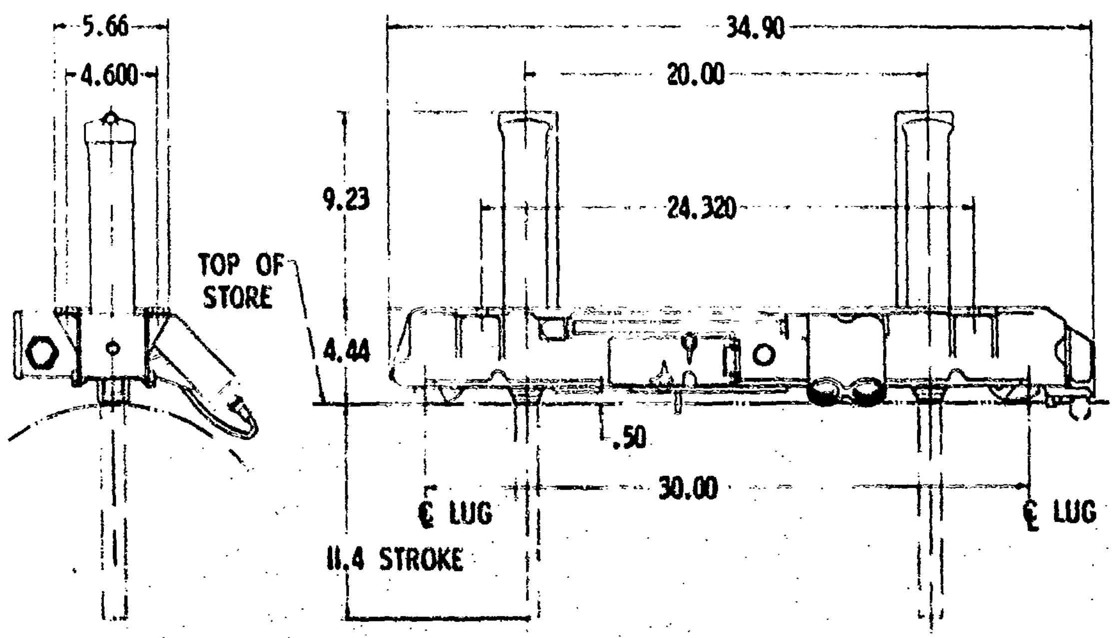


Figure 25. 30-Inch Ejector, Dimensional Schematic

AUTOBIOGRAPHY - PAUL F. PETERSON

Mr. Peterson joined North American Aviation in 1940 and has worked almost exclusively on armament for over 35 years. Early work included gun installations on P-51 through F-107 aircraft. Suspension, release, and ejection devices for several bombers from the B25 through the B70 were also designed. He has also developed a number of specialized armament devices including guns, bomb ejectors, missile launchers, and release mechanisms applicable to many other airplanes.

He is presently Manager - Weapon Systems Design, and in this capacity manages all armament development activities on the B-1 Air Vehicle. These activities include all facets of weapons carriage (both nuclear and conventional), and development of mechanisms for launcher rotation, weapons bay door operation, and launcher clip-in.

EVALUATION OF A GN_2 POWERED, MECHANICALLY LINKED DUAL EJECTOR SYSTEM
(U)
(Article UNCLASSIFIED)

by

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&
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ABSTRACT. This report contains a description and evaluation of a Naval Weapons Center (NWC) designed dual ejector system that is cold gas (GN_2) powered and uses hydraulic fluid as a media for ejection stroke extension. The report describes the construction of the system, tests performed and data obtained. The system has two identical ejector housing assemblies, each containing hydraulic fluid, a fluid displacing piston and telescoping pistons for ejection stroke. The GN_2 pressure housing assembly has a piston for power output. The fluid displacing pistons and the GN_2 power piston are mechanically linked to provide positive dependency in movement. For parallel ejection, ejector extension is equal with the ejection force proportionally equilibrating the reacting forces encountered by the individual ejector assemblies. This proportional force distribution between ejector assemblies during parallel or pitch angle ejection requires no sensors or regulators. Using hydraulic fluid as a media for ejector extension allows control of the individual telescoping piston length of travel if other than positive parallel ejection is desired. By manually controlling the amount of fluid available for extension in either ejector assembly, variations in stroke length of the two ejector assemblies telescoping pistons can create stores pitch angle change or angular rate inducement. The ejection force is all on one of the two ejector assemblies for the angular rate ejection mode.

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INTRODUCTION

This report provides descriptive and initial test data for a dual ejector system which is cold gas (GN_2) powered and enables selected pitch attitude or pitch rate of aircraft store ejection, regardless of external perturbances during the ejection sequence. This design will consistently eject a store into a safe and predictable trajectory.

Ejector systems presently in use cannot react to unknown infinite variations in forces and moments acting upon the store during the ejection cycle, particularly at supersonic speeds. As the requirements for aircraft and store delivery speeds increase, the nonuniform forces acting upon the store become more critical to predictable safe store separation. Without consistently predictable launch of the store with minimal perturbances, a large amount of delivery error is inevitable. There is evidence that these forces and moments acting upon the store during the launch cycle constitute the largest single source of bomb dispersion. These launch dispersions are referred to as mal-launch dispersion and are defined as the variation in forces acting upon the store during the entire ejection cycle until the bomb is clear of the nonuniform flow field surrounding the launch platform.

It is estimated that mal-launch dispersion contributes more delivery error than the combined effects of aim error and in-flight ballistic dispersion error (caused by imperfections introduced in the manufacturing and handling of a store, such as bent fins, etc.) during a typical supersonic (~ 800 kts) store ejection from an aircraft[1]. Under this launch condition, it is estimated the aim error for computer aided delivery systems contributes an average of 10 mils CEP (circular probable error) of dispersion, in-flight ballistic dispersion contributes 4 mils CEP and mal-launch contributes up to 20 mils CEP. If mal-launch dispersion error can be reduced to a figure comparable to the 10 mil aim error, the single bomb hit probability can be improved from approximately 0.31 to 0.59, with a real effectiveness (hit probability) improvement of 90%.

The dual ejector system described herein, by enabling a selected parallel, pitch attitude change or pitch angular rate of ejection, will guarantee consistently safe store separation from the aircraft with no launch envelope limitations. Improved aiming devices being incorporated in currently operational aircraft will tend to reduce aim error toward the 4 mil CEP magnitude of in-flight dispersion. If both aim error and mal-launch dispersion can be reduced to this magnitude, real effectiveness (single-hit probability) improves to 0.89 - a "whopping" overall accuracy improvement of 187%.

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[1] Maestri, Raymond R., and Schindel, Leon H. (U) Self-Compensating Store Ejection. NOLTR 74-3, Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland, 5 February 1974.

The capability to vary the ejection force is a highly desirable feature of a stores ejection system. Variance of ejection force, relative to stores weight, enables achievement of desired end of stroke velocity which is important due to inertial loads that are imposed by the delivery aircraft. Variable ejection force is possible with an ejection system powered by a cold gas pressure source. The use of a noncontaminating power source for ejection reduces cleaning maintenance to a bare minimum. As an example, there has been no maintenance required on the dual ejector system used for the tests described in this report after 325 ejection cycles. The use of hydraulics in a closed system (i.e. no lines, pumps, fittings, reservoirs or restrictions), pressurized only during ejection stroke duration, and with designed sealing capability, should eliminate the objectionable leakage characteristics of most present hydraulic systems. Experience has shown that the use of the Greene Tweed (GT) T-seals in the hydraulic and pneumatic systems should reduce the maintenance to almost zero. The use of standard O-ring seals is not recommended for this application. A list of current aircraft which presently use the GT seals is shown in appendix A. There have been literally no failures of this type of seal in the applications since their introduction.

This is a modular system and positive parallel ejection is the systems primary function. The pitch attitude control, pitch rate control, and variable power control with pressurized GN_2 are additional features that can be incorporated into an ejector system design, if requirements dictate. The use of a pyrotechnic cartridge activated device (CAD) in place of the cold gas source is optional with this system, but is not recommended due to maintenance requirements.

Cold gas pressure settings ranging from 1000 to 3000 psig were tested to determine efficiencies at the selected pressures. Input pressure, accelerations, applied force and distribution of pressure were measured and recorded. A Mk 82 bomb (actual weight - 489 lb) with a conical tail fin was used for these tests. The nose cone was grooved to allow a steel cable to apply external force, simulating induced moments of 16,000 or 32,000 in.-lbs on the store. Parallel ejection with, and without, externally applied force was tested. Store pitch angle and pitch rate establishment, with and without loads, was tested.

DESCRIPTION

TECHNIQUE COMPARISON

Current bomb rack ejector systems are powered by hot gas with single or dual ejector piston systems. Propellant cartridges or CADs generate expanding hot gasses which extend the pistons, and provide ejector force. Two ejector pistons provide for better distribution of the available ejection forces on the weapon body. Since the stores to be suspended and released vary considerably in geometric shape and weight, their respective center of gravities may vary along a longitudinal axis relative to the ejector pistons. While suspended on the aircraft during flight, the aerodynamic flow field about the aircraft and store induce external forces and moments on the weapon which may cause pitch, yaw and rotation of the weapon during ejection. A brief comparison of a gas linked and mechanically linked dual ejection system is provided in the following, together with the advantages and disadvantages of each system, respectively. For discussion purposes, it is assumed that both systems are CAD powered.

GAS LINKED SYSTEM

A gas linked ejector system typical of those currently in service, is shown in Figure 1. A breech assembly with 2 cartridges is connected to each telescoping piston ejector assembly by a conduit. Since there is no physical connection between the telescoping pistons, each piston functions independently of the other. In order to compensate for CG tolerance and aerodynamic forces and moments (if known), orifices can be inserted into the conduits to meter or change the flow of gases causing an increase or decrease in the forces required to overcome these external resistances. The variability of the external resistances is likely to create an inconsistent, nonparallel ejection stroke due to the force application at the point of least resistance.

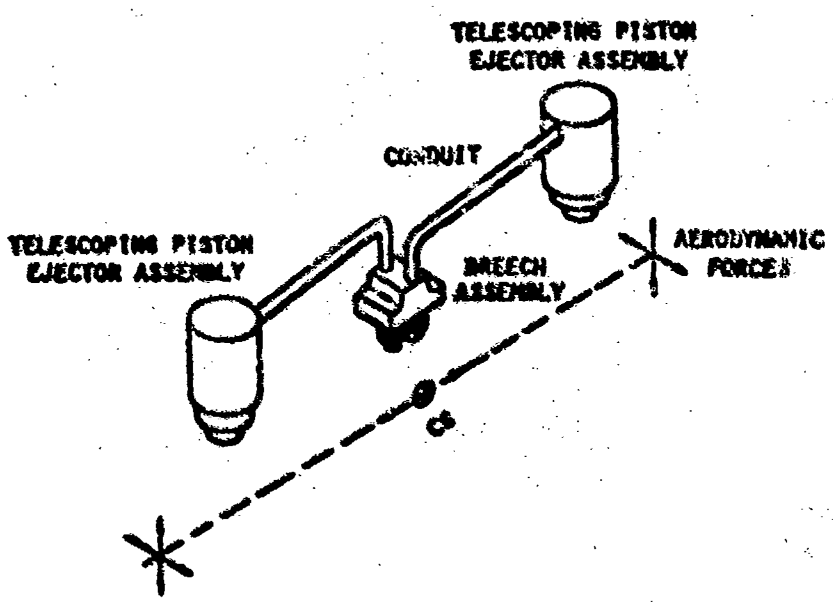


Figure 1. Gas Linked Ejector System.

MECHANICALLY LINKED SYSTEM

A mechanically linked ejector system schematic is shown in Figure 2. The breech assembly contains two cartridges and a power piston which is mechanically linked to the two ejector assemblies. This linking results in dependent ejector strokes in that one piston assembly cannot extend without the other. The force application occurs at the point of greatest resistance, and both pistons extending together give repeatedly parallel consistent stores ejection. No adjustments are required to overcome changes in CG and aerodynamic forces.

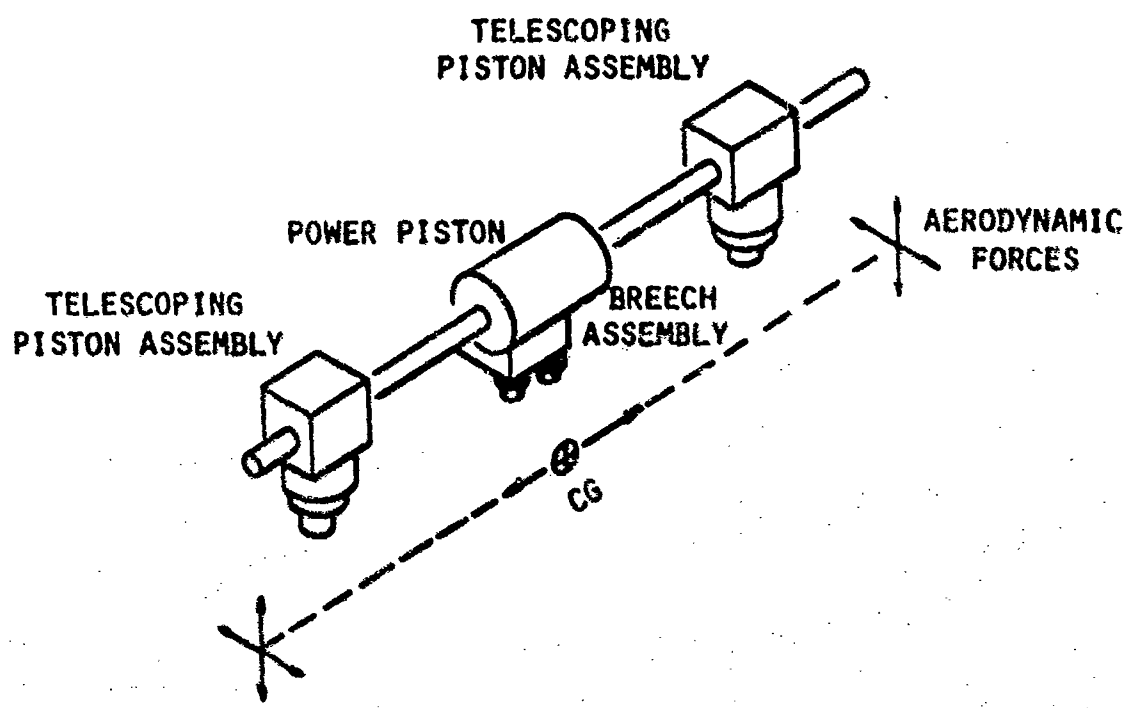


Figure 2. Mechanically Linked Ejector System.

Mechanically linked systems are unaffected by changes in weapon CG and aerodynamic flow field forces. Mechanical dependency automatically applies the ejection forces to the point of greatest resistance, while gas independent systems apply forces to the point of least resistance, thereby compounding a possible undesirable separation condition. Mechanically linked ejectors can maintain store pitch control automatically over the range of the release envelope, while gas systems require an adjustible orifice or metering system which is usually set prior to launch for a specific set of release conditions.

Gas ejector systems have the advantage over mechanicaly systems in that they are usually smaller and lighter in weight. This brief comparison of the two ejector systems show that the mechanically linked dependent ejector systems have several advantages over the gas linked systems.

NWC DESIGNED DUAL EJECTOR SYSTEM

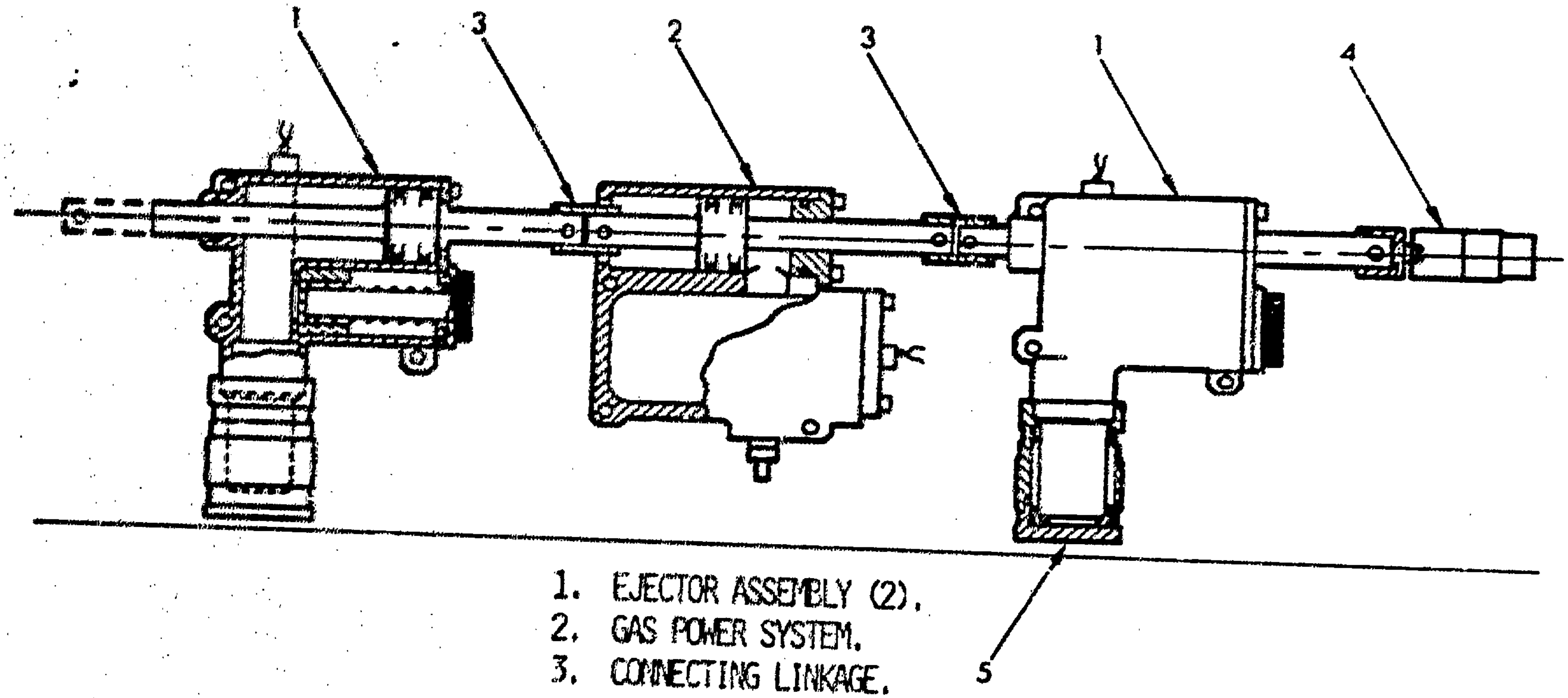
The NWC designed dual ejector system assembly (Figure 3) consists of two ejector assemblies (Figure 3, Item 1), a gas pressurized power system (Item 2), connecting linkages (Item 3), pressure sensors and control valves and a release unit (Item 4). The connecting linkage mechanically connects the gas power system output piston and both input pistons of the ejector assemblies, so that each of the three pistons become movement (ejection stroke) dependent of the others.

Ejector Assembly

Each ejector assembly (Figure 4) consists of a housing (Figure 4, Item 1), an input piston (Item 2), a hydraulic oil chamber (Item 3), a floating piston and spring (Item 4), an adjustable stop (Item 5), a telescoping piston (Item 6) and a return spring and weapon contact adjustment assembly (Item 7). The floating piston, spring and adjustable stop is part of an adjustment device for varying the stroke length. The unit is also equipped with a pressure transducer (Item 8) for recording the pressure during the ejection stroke.

Ejector Stroke Adjustment Device

Each ejector assembly is equipped with an adjustment device for reducing the telescoping piston ejector stroke length. The stroke length control feature is made possible by a separate piston and spring (Figure 4, Item 4) and an adjustable stop (Item 5) which can be positioned to effect a change in the volume of the hydraulic oil chamber (Item 3). During ejection, oil is displaced within the chamber and the adjustable stop controls the volume of oil which is diverted into a closed bypass in the housing. The preselected amount of oil diverted into the bypass detracts from the total volume of oil available to extend the ejector



1. EJECTOR ASSEMBLY (2).
2. GAS POWER SYSTEM.
3. CONNECTING LINKAGE.
4. RELEASE UNIT.
5. EJECTOR FOOT (2).

Figure 3. Dual Ejector System.

pistons, thereby shortening the ejector foot stroke to the selected length. This results in one ejector piston ejecting the nose (or tail) of the store downward during the initial ejection sequence while the other ejector piston pushes the opposite end of the store downward after a delay, with both pistons reaching their selected stroke limit at the same time. The adjustment device for either (or both) of the ejector assemblies can be adjusted for any ejection stroke limit between zero and 6.0 inches on the test model, as required.

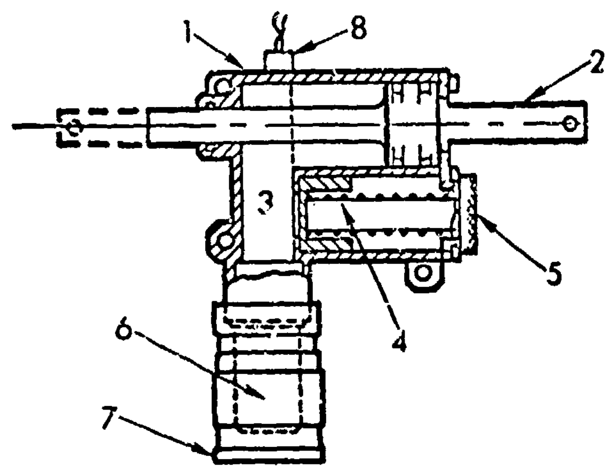


Figure 4. Ejector Assembly.

The cold gas power system (Figure 5) consists of a housing (Figure 5, Item 1), a power output piston (Item 2), a pressure chamber (Item 3), a filler valve (Item 4) and a pressure sensor (Item 5). The gas chamber was pressurized from a pre-pressurized bottle system during this evaluation.

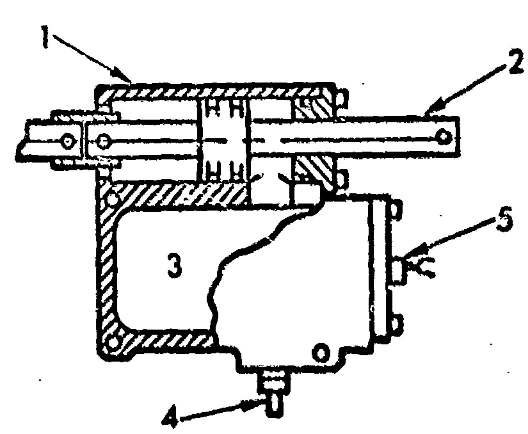


Figure 5. Gas Power System.

TEST OBJECTIVES

Testing of the dual ejector system is to evaluate the following:

a) Efficiency of Ejection - The effect on system performance with variations in GN_2 ejection pressures.

b) Ejection Force Distribution - The inherent design characteristics of dependent dual ejection which dictate the ejection forces to be applied proportionally to the points of encountered resistance. The effect on force distribution with variations in ejection stroke length.

c) Attitude Change - The ability to induce or correct store pitch attitude by variations in ejector stroke length.

d) Externally Applied Force - The ability of the dual ejector system to balance externally applied forces and CG placements.

TEST SET-UP

The dual ejector system test set-up consisted of a 10,000 psi GN_2 psi cart attached to a pneumatic control panel for control of release and ejection pressures. The release pressure was set and then held constant for every test while the ejection pressure was incremented as required to meet the test plan. Release of the weapon was controlled through a basic fire control panel used for functioning standard bomb ejector cartridge systems.

A cable arrangement was provided which applied a downward force on the nose of a weapon to simulate an externally applied force, inducing a nose down rotation of the weapon during release (See Figure 6). The amount of cable force was controlled by means of a piston rod in a pneumatic cylinder, 8 feet in length, attached to the ends of the cable. The pounds force/pressure (psi) is shown graphically in Appendix A on Figure A-1. The cylinder was attached to a load cell to measure the applied load during ejection.

The dual ejector system was mounted to a steel frame over an ejection pit. The ejector system had 3 pressure transducers, one for the GN_2 chamber and one on each hydraulic ejector assembly. The Mk 82 bomb had accelerometers mounted on the bomb, forward and aft of the ejectors, and an equal distance from the center of the two ejectors. The store suspension mechanism and the power detent were made from a NADC lock-on coupling device (Figure 7). For test purposes, the availability of the NADC coupler precluded the need to design a new hood/lug device, or integrate an existing hook system. A linkage was built to operate the power

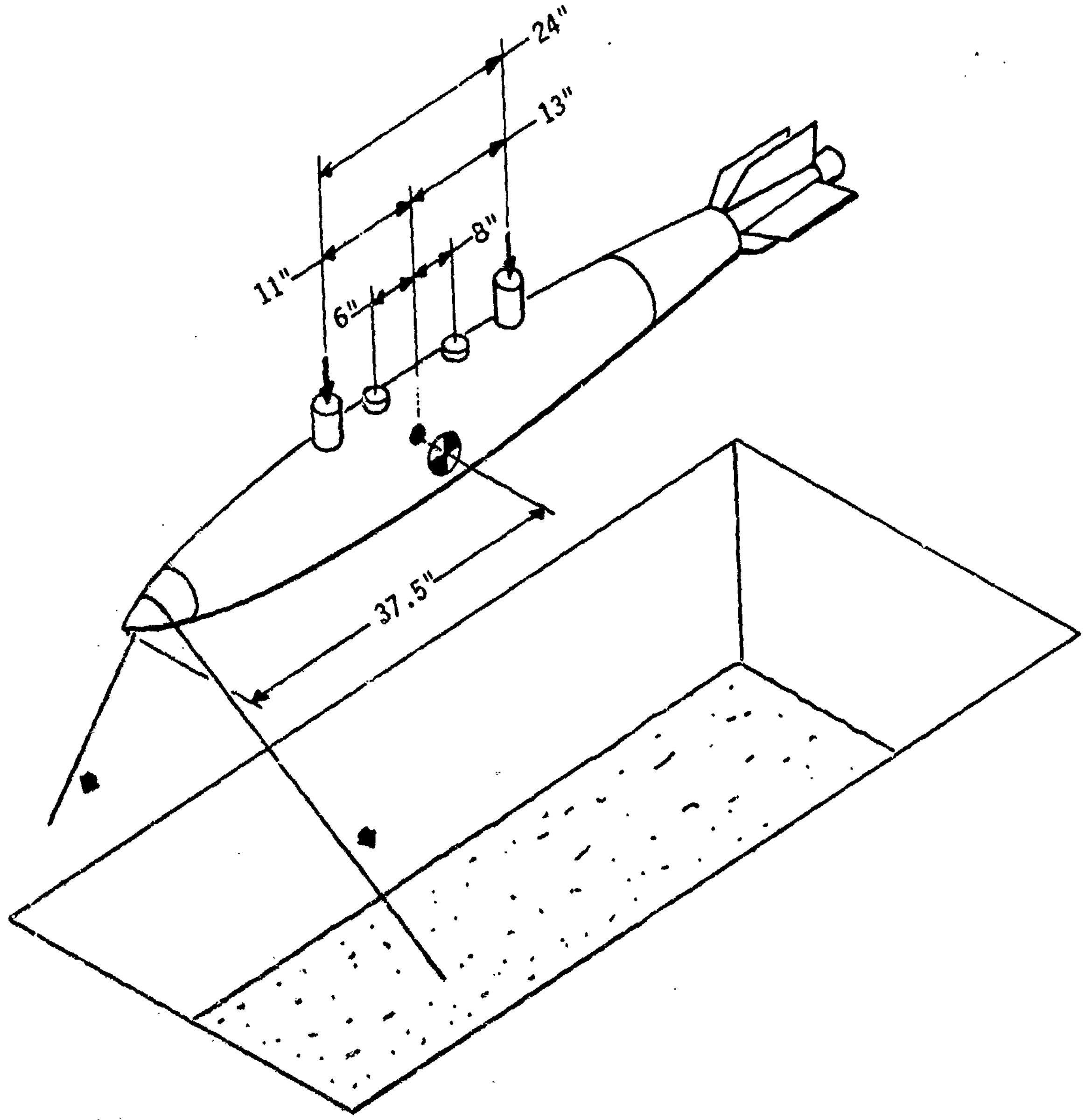


Figure 6. Mk 82 Bomb Ejection Test Set-up for Application of External Force.

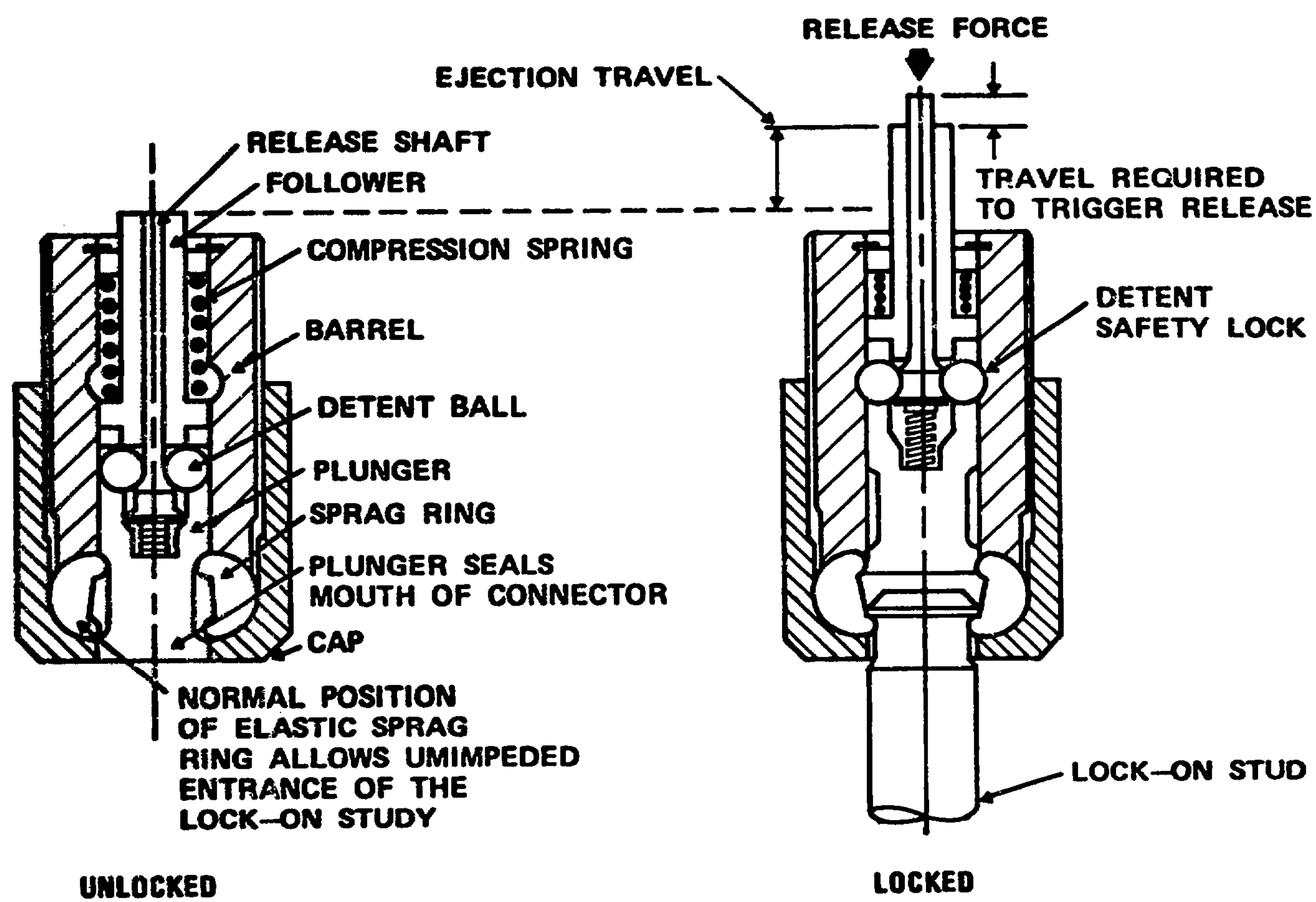


Figure 7. NADC Lock-On Coupling.

detent and weapon release couplers simultaneously. A small piston assembly was attached to the linkage and GN_2 pressure was used to actuate the mechanism. The release pressure was contained in a small pressure bottle, independent of the ejection pressure chamber, and was routed to the release piston via a solenoid valve. The firing pulse from the fire control panel actuated the solenoid valve.

TEST DATA

A 14 channel magnetic tape recorder was used to record the timing, hydraulic and GN_2 pressures, accelerations and load cell signals. The recorded data was later computer processed and reproduced. Examples of these data and results presented herein illustrate the functional capabilities of the dual ejector system.

Ejection Tests With No Applied External Force

Table I lists tests conducted without externally applied forces which are discussed in this report. Appendix A contains a complete listing of the tests performed. Data from 2 or 3 pressure ranges will be presented for comparison of performance parameters.

TABLE I. Ejection Test Conditions With No Externally Applied Force.

SERIES NO.	TEST NO.	EJECTOR STROKE (in.) FWD	AFT	GN_2 PRESSURE (psig)	EXTERNAL FORCE (lbs)
1	9	6.0	6.0	3000	0
2	9	6.0	4.5	3000	0
3	3	6.0	3.0	3000	0

A graph of the approximate time of ejection vs variations in the operating GN_2 pressures, using the Mk 82 bomb, is shown in Figure 8. A family of curves could be generated for various weight stores. Figure 9 shows characteristic pressure curves of the pressurized gas (GN_2) within the power system during ejection for various pressures. These pressure curves are typical regardless of the stroke settings and the applied external loads. As the power piston displaces within the housing, the pressure varies by the relationship $P_1V_1=P_2V_2$. No flow of GN_2 through conduits is required for functioning of the ejector pistons. Simple volumetric expansion from 65 to 75 in^3 is all that occurs.

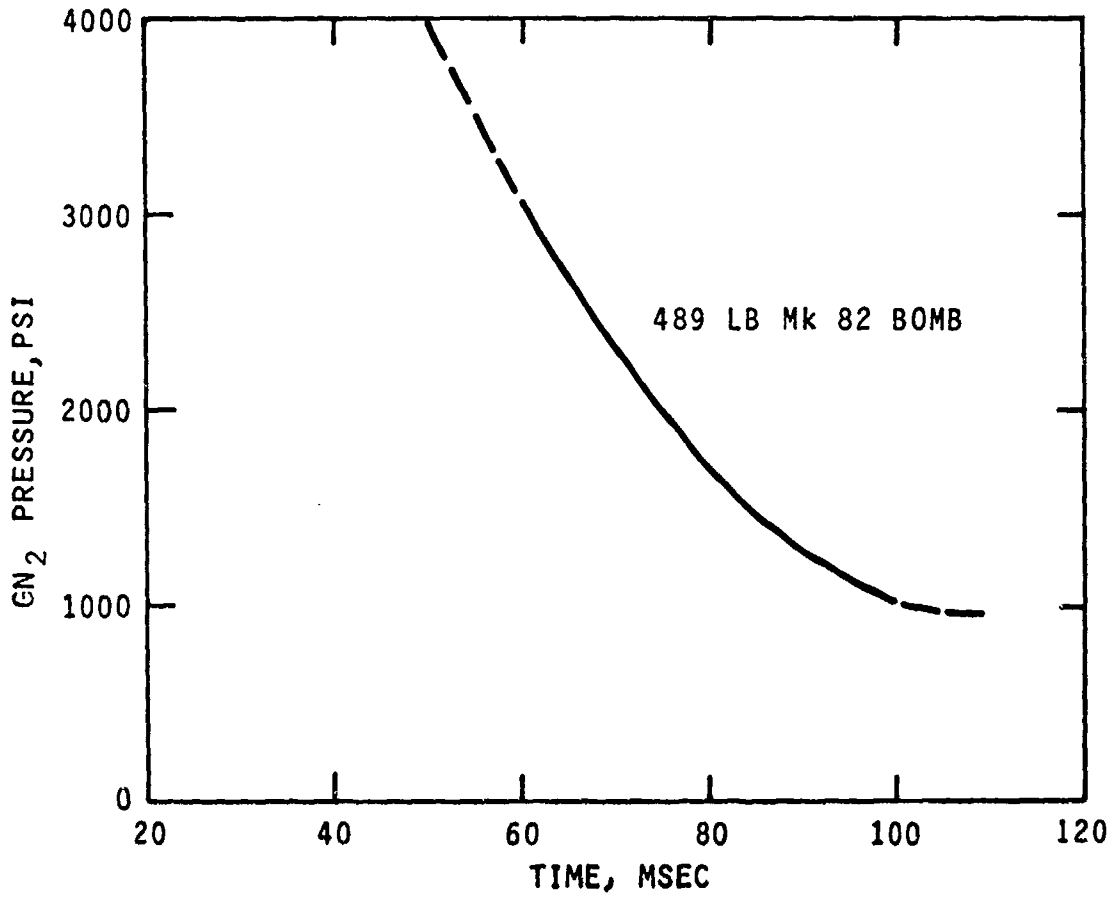


Figure 8. Six-Inch Ejection Stroke Time vs Ejection Pressure - No External Force.

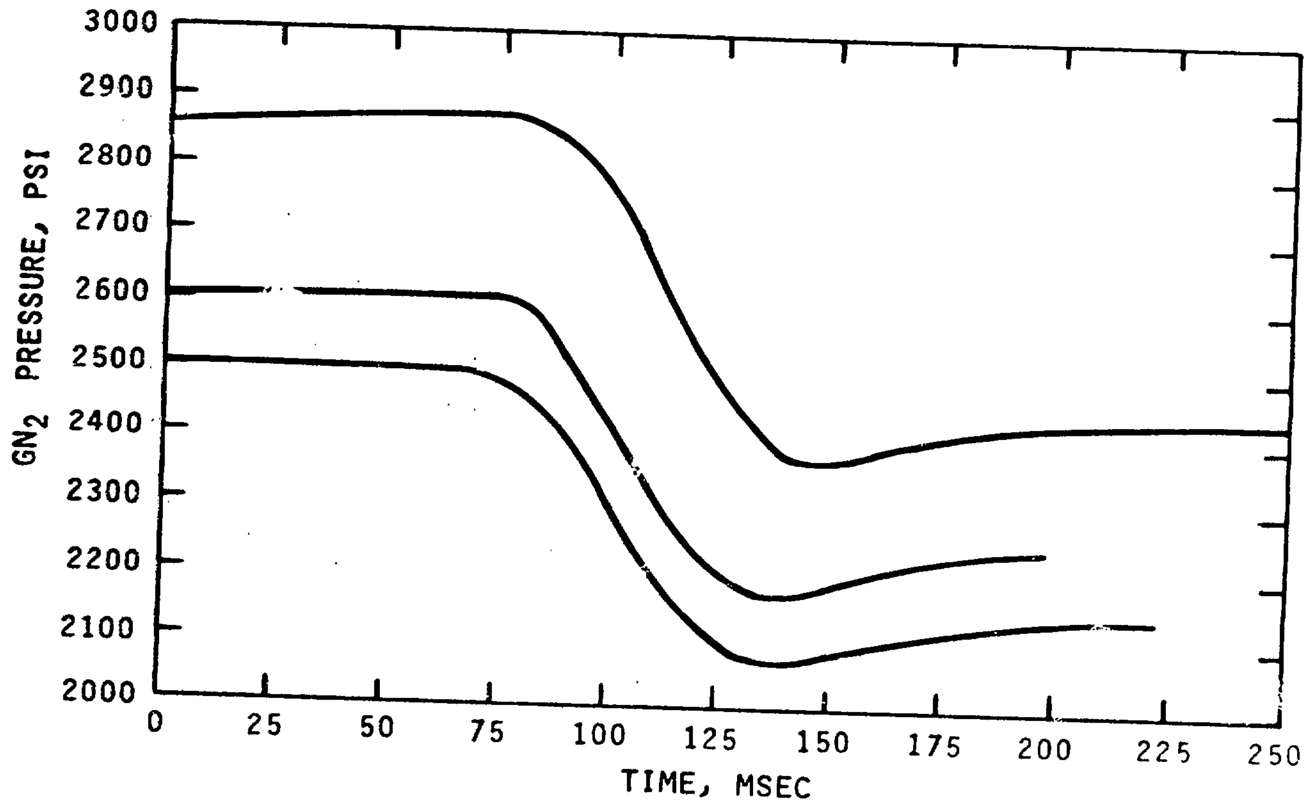


Figure 9. Characteristic Gas (GN_2) Pressures vs Time (During Ejection).

The slope of the curve is a function of the initial volume of the GN_2 chamber. A larger initial volume would give a better performance curve, since the pressure would decrease very little throughout the ejection stroke. This indicates the availability of nearly as much pressure at the end of the ejection stroke as at the beginning of the stroke. The losses within the ejector system were estimated to be a function of the hydraulic and pneumatic seals and the ejector piston return springs. Prior to ejection, the seals in the hydraulic units are at zero pressure until the load is applied. The static friction of the seals and the spring loads of the return sleeve assemblies must be overcome before the ejectors can move. The initial static load of the pneumatic seals is a significant variable which increases as the pressure increases. Since the pneumatic system is under pressure prior to ejection, this static force could be several hundred pounds. Once the system begins to function, this force is reduced to approximately one-third the initial value. In general, the static friction (under pressure) is greater than the running friction after the system begins the ejection sequence by a factor of 3. An indication of the losses was determined by measuring the pressures within the hydraulic assemblies and comparing these with the gas (GN_2) pressure. The operating efficiency of the ejector system was then calculated from the formula:

$$\text{EFF} = (\text{PSI}_{\text{oil}} \div \text{PSI}_{GN_2}) \times 100$$

This efficiency curve is graphically presented in Figure 10 and appears to approach an upper limit of 85 to 90%. This curve is for ambient conditions; additional testing will be required to determine the efficiency as a function of temperature.

Parallel Ejection

To obtain parallel ejection, the pressure forces must be distributed, as required, to maintain a stable store attitude during the ejection stroke. The total force available for ejection is the sum of the forces at each ejector piston. The ability to accomplish this function automatically, without sensors or regulators, is inherent in the design of positive displacement. Figure 11 shows the distribution of pressure between each ejector piston assembly during ejection and the total pressure summation curve. This total (sum of) pressure curve for this ejector system is represented by the formula:

$$(P_f + P_a) = \text{Pressure } (GN_2) \times \%\ \text{Efficiency}$$

Where:

P_f = Forward ejector pressure

P_a = Aft ejector pressure

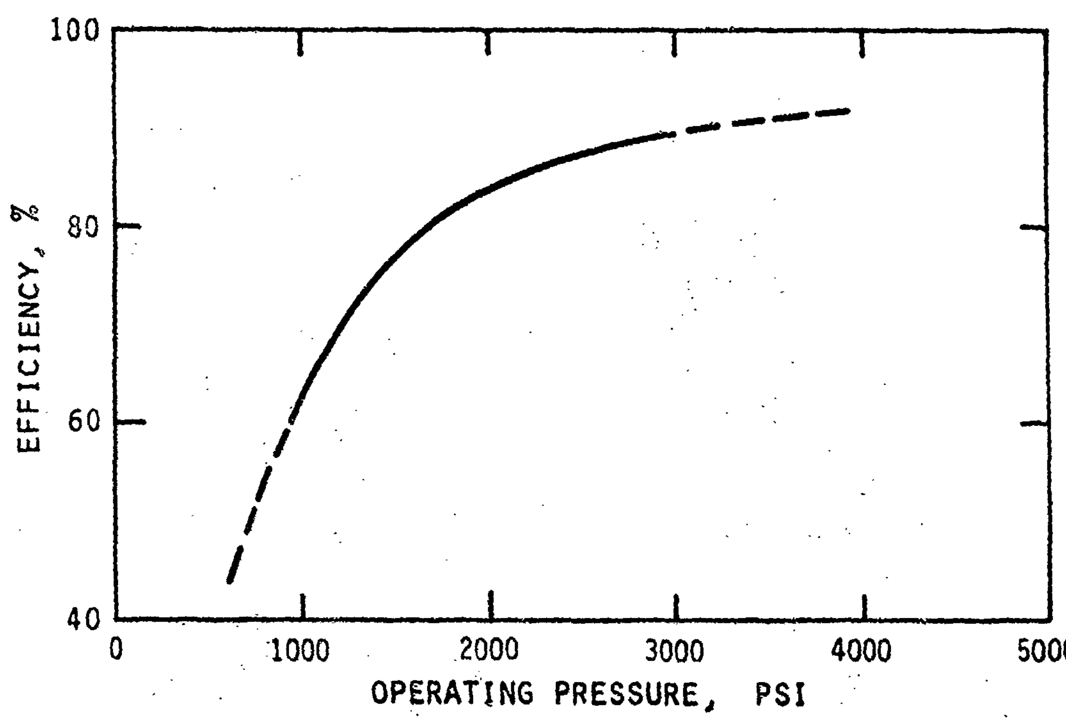


Figure 10. Ejector Gas (GN_2) Pressure Operating Efficiency.

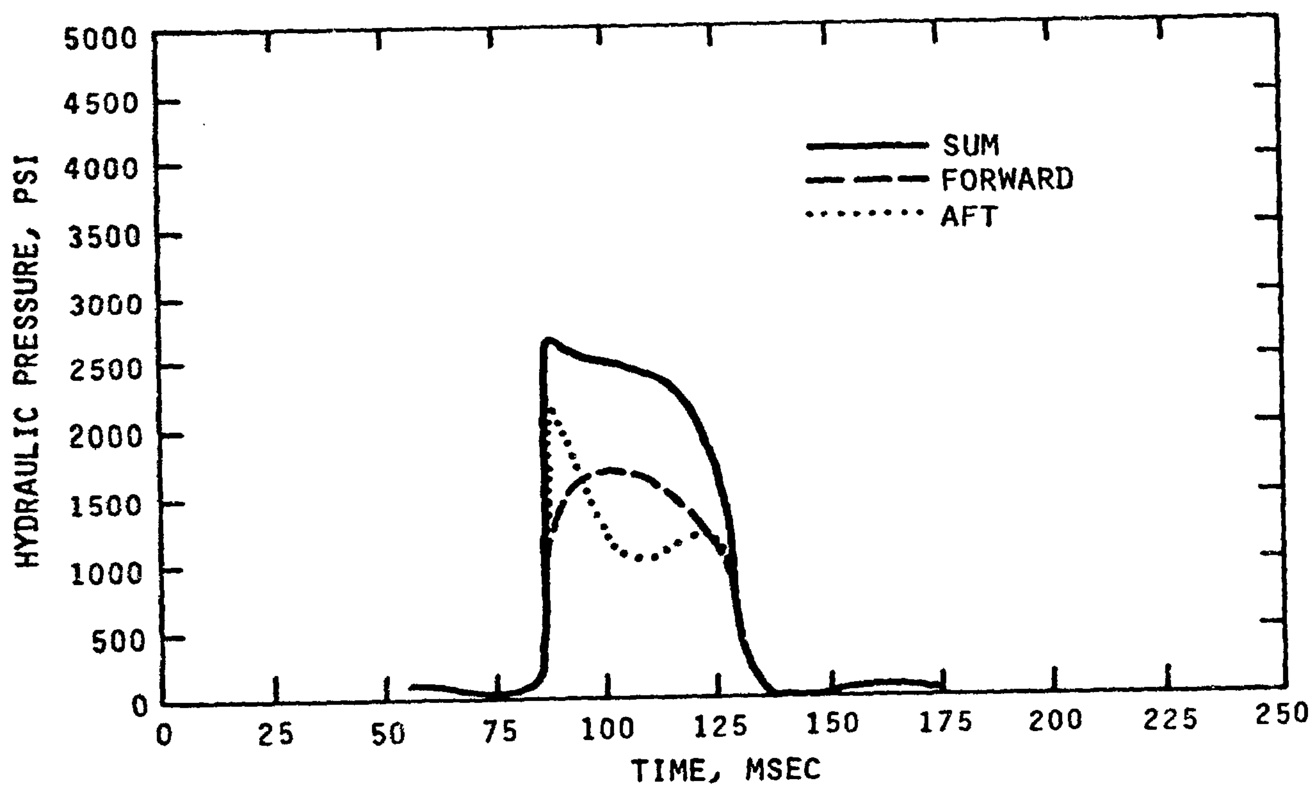


Figure 11. Ejector Piston Distribution and Summation of Pressures 6/6 In. Strokes, No External Force, 3000 PSI, Mk 82 Bomb.

The curves reflect what is taking place internally during ejection. This distribution of pressure indicates the actual distribution of ejector forces on the store during the ejection cycle. The actual force application on the store is shown on Figure 12 and takes into account the area of the ejector pistons as a function of stroke length. The curve is the total force being applied by the ejector system to the store. Figure 12 shows the force is largest during the first piston extension, or the one with the largest area. At the time the smaller piston starts to extend, the area has been reduced approximately 50% and the force applied to the store is proportionately reduced. During the last 0.5 in. of travel of the input piston (Figure 4, Item 2) this piston impacts a snubbing device and the ejection force drops to zero which is reflected in the force application curve of Figure 12. A small adjustment of this snubber can extend the power stroke further, but the additional amount of force being applied at this point is relatively small.

Non-Parallel Ejection

For test simplicity, only two adjustments were used for non-parallel ejection tests. The second (smaller) piston extension of 3.0 inches was divided into two increments enabling the stroke of the aft piston assembly to be reduced by 1.5 or 3.0 inches. With this arrangement, the full 6.0 inch ejection stroke of the aft piston could be reduced allowing the forward piston to reach its fully (6.0 inch) extended position while allowing the aft piston to extend only to 4.5 or 3.0 inches. (Both the forward and aft pistons, on test model, were fully adjustable for any stroke length of zero to 6.0 in.).

A series of tests were performed to evaluate the functions with one of the piston stroke lengths extending to only 4.5 or 3.0 inches. Figure 13 shows pressures within the ejector assemblies with 1.5 inches of stroke reduction induced in the aft piston (limiting the aft piston to a 4.5 inch stroke). It is noted that all of the pressure is being applied to the forward piston during the initial stroke (while the enlarged aft piston chamber is filling with oil). A short time later, the pressure in the aft assembly rapidly increases while the forward piston pressure is decreasing. At one point, the pressures are equal; eventually, the system is snubbed with both pressures dropping to zero at the end of the strokes. This induced stroke change causes an initial downward ejection of the nose of the store by the first piston, inducing a pitch angular rate until the second piston begins to apply force. The force of the second piston dampens the pitch rate, stabilizing the store at the selected pitch angle, and continues to maintain this attitude throughout the remainder of the stroke. This is a sure method of maintaining a fixed angle in the store attitude as a means of meeting a prescribed launch requirement, regardless of nonuniform external forces acting upon the store.

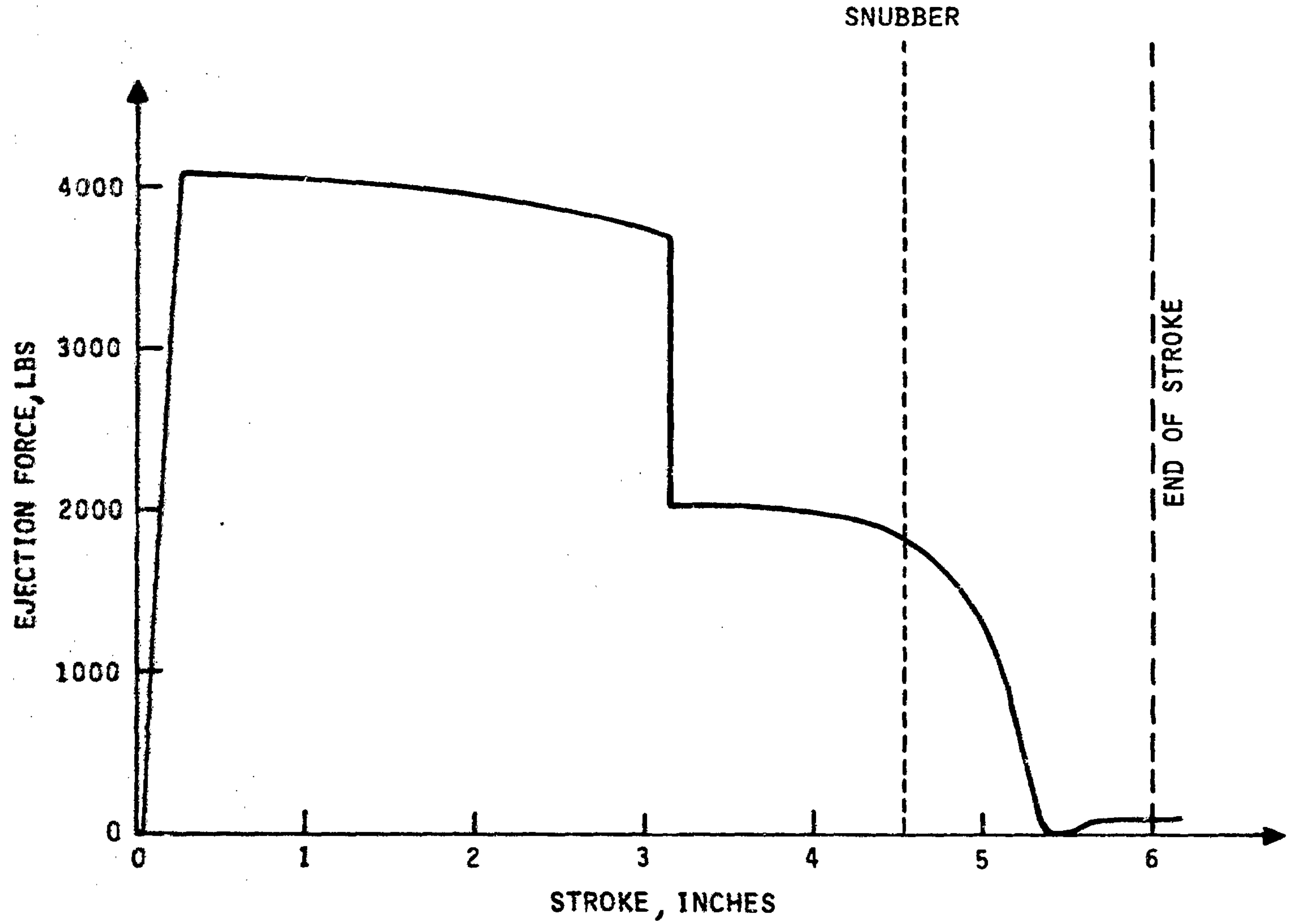


Figure 12. Force Application on Store During Ejection - 6/6 In. Strokes, 3000 PSI, Mk 82 Bomb.

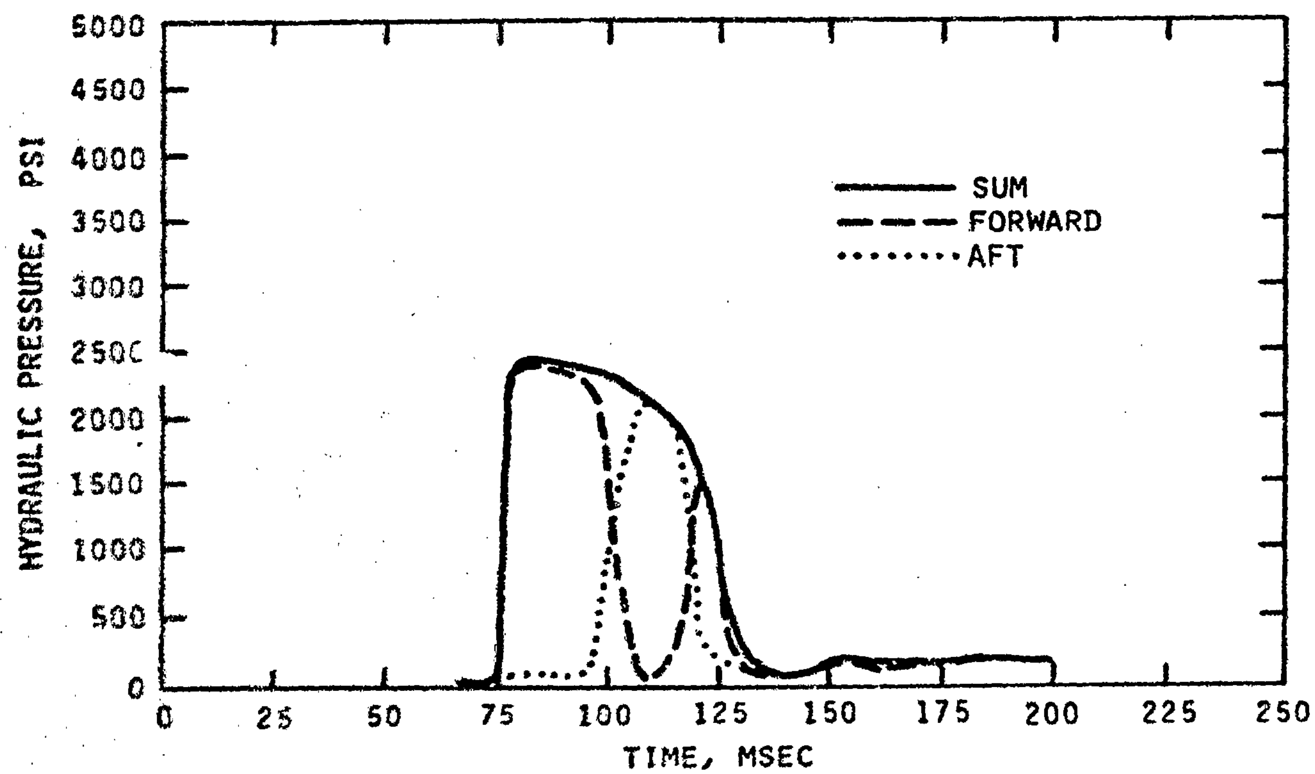


Figure 13. Forward and Aft Ejector Pressure Summation - 6/4.5 In. Strokes, No External Force, 2500 PSI, Mk 82 Bomb.

A 3.0 inch aft piston stroke reduction was induced and evaluated to determine the effect on store ejection. Figure 14 shows the pressure curves of the hydraulic assemblies with this induced ejection stroke change. It should be noted that the aft piston does not receive any pressure throughout the ejection cycle. Only the forward piston was applying ejection force inducing a pitch angular rate throughout the ejection cycle. The actual pressure curve of Figure 14 (6 in./3 in. stroke) is the same as the sum of pressures for a 6 in./6 in. or a 6 in./4.5 in. stroke (as shown on Figures 11 and 13, respectively) except all the pressure is applied to one piston.

Acceleration and Velocity During Ejection

The acceleration and velocity curves of the Mk 82 bomb at various ejection pressures are shown on Figures 15 and 16, respectively. These curves represent a 6 in./6 in. parallel ejection stroke. The velocity curves are integrations of the recorded acceleration of the forward and aft accelerometers on the bomb. Additional acceleration and velocity data for the 3000 psi ejection tests (without externally applied loads) are contained in Appendix B, Figures B-1, B-2 and B-3.

Ejection Tests With Applied External Force

Table II is a list of the tests in this report with force applied externally to the Mk 82 bomb:

TABLE II. Ejection Test Conditions With Externally Applied Force.

SERIES NO.	TEST NO.	EJECTOR STROKE (in.) FWD	EJECTOR STROKE (in.) AFT	GN_2 PRESSURE (psig)	EXTERNAL FORCE (lbs)
4	3	6.0	6.0	3000	427
5	3	6.0	6.0	3000	853
7	3	4.5	6.0	3000	427
8	3	4.5	6.0	3000	853

Parallel Ejection

The first tests with externally applied force were conducted with the stroke lengths of the ejector assemblies equal. Figure 6 illustrates the CG location and the points of force application on the Mk 82 bomb. Two values of force were applied to simulate a nose down moment of 16,000 and 32,000 in-lbs. These moments were simulated with the application of a 427 lb load for 16,000 in-lbs and 853 lb for 32,000 in-lbs. It was predicted the ejector should be able to maintain a parallel store attitude up to 32,000 in-lbs moment nose down on the weapon. A graph of the distribution of ejector chamber pressures for 16,000 in./lbs nose down moment is shown on Figure 17 and for 32,000 in./lbs on Figure 18. The

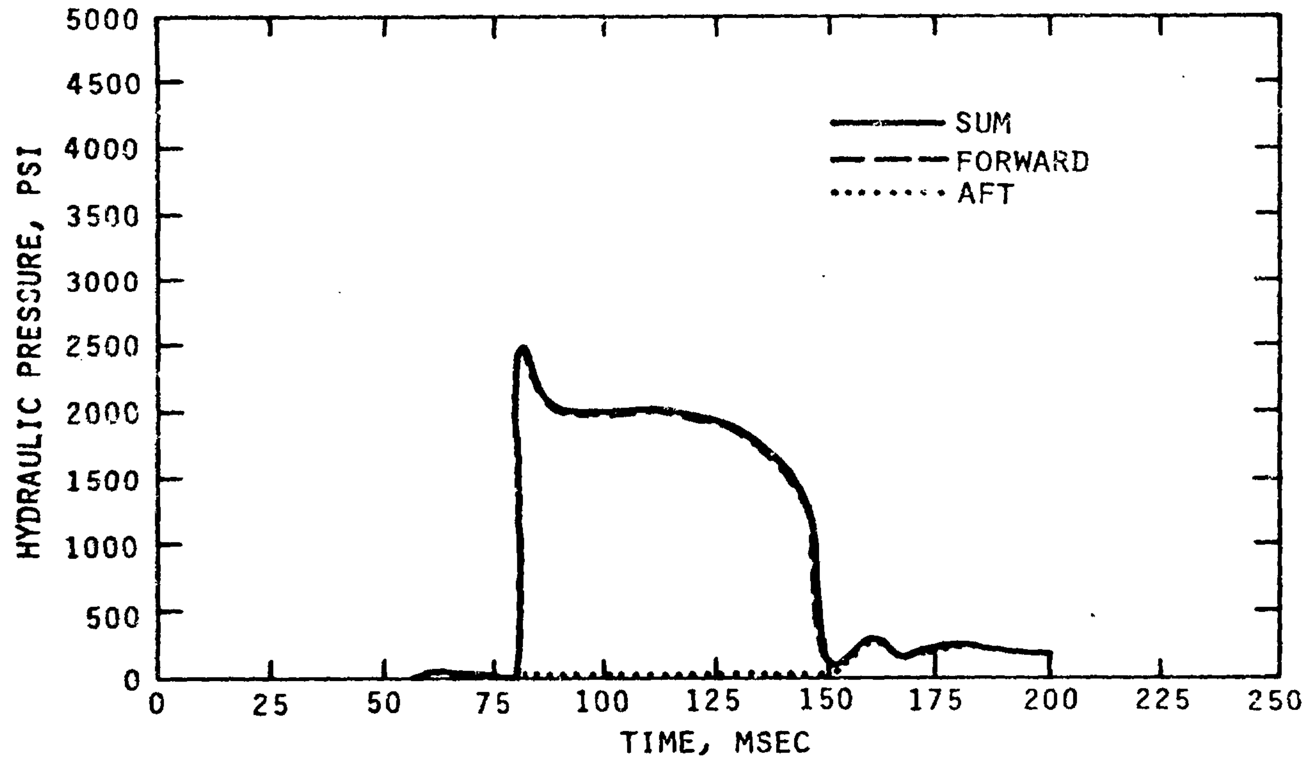


Figure 14. Forward and Aft Ejector Pressure Summation - 6/3 In. Strokes, No External Force, 3000 PSI, Mk 82 Bomb.

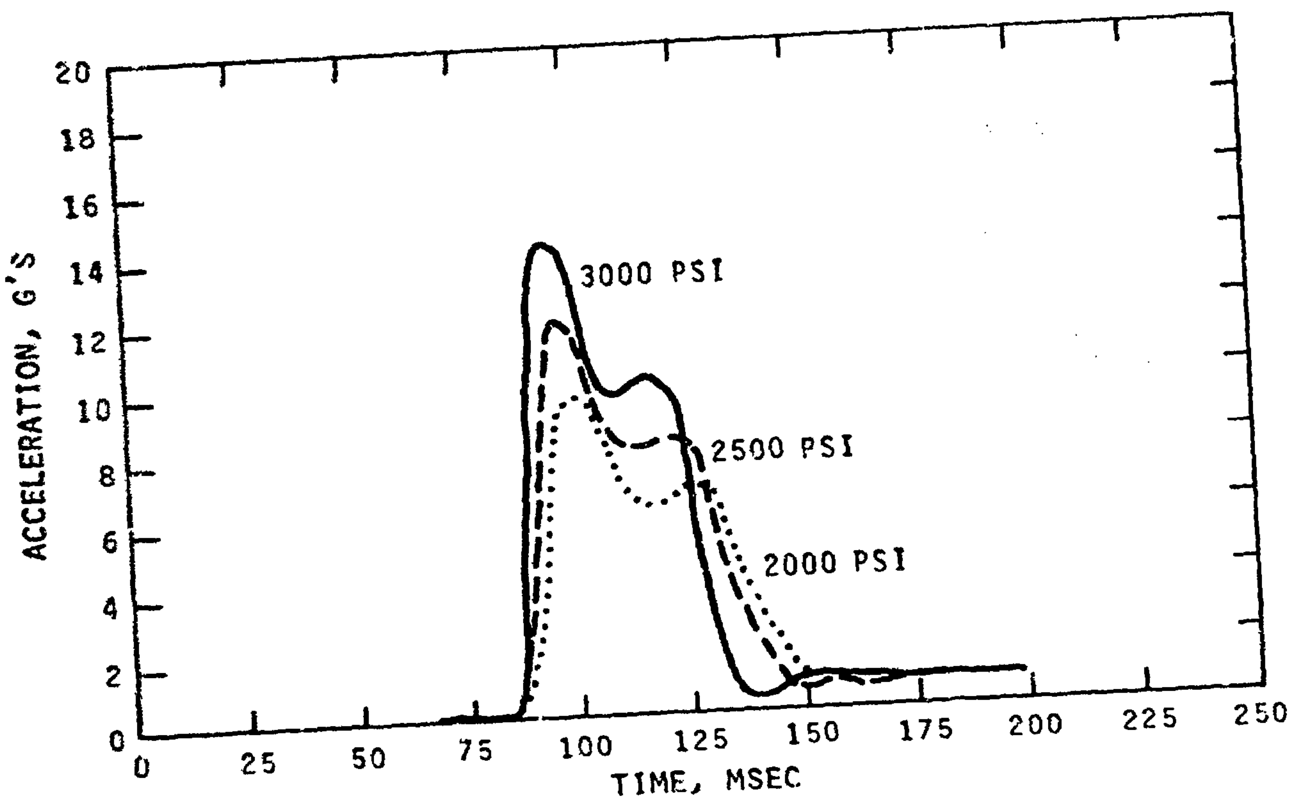


Figure 15. Ejection Acceleration of Mk 82 Bomb (Conical Tail Fin).

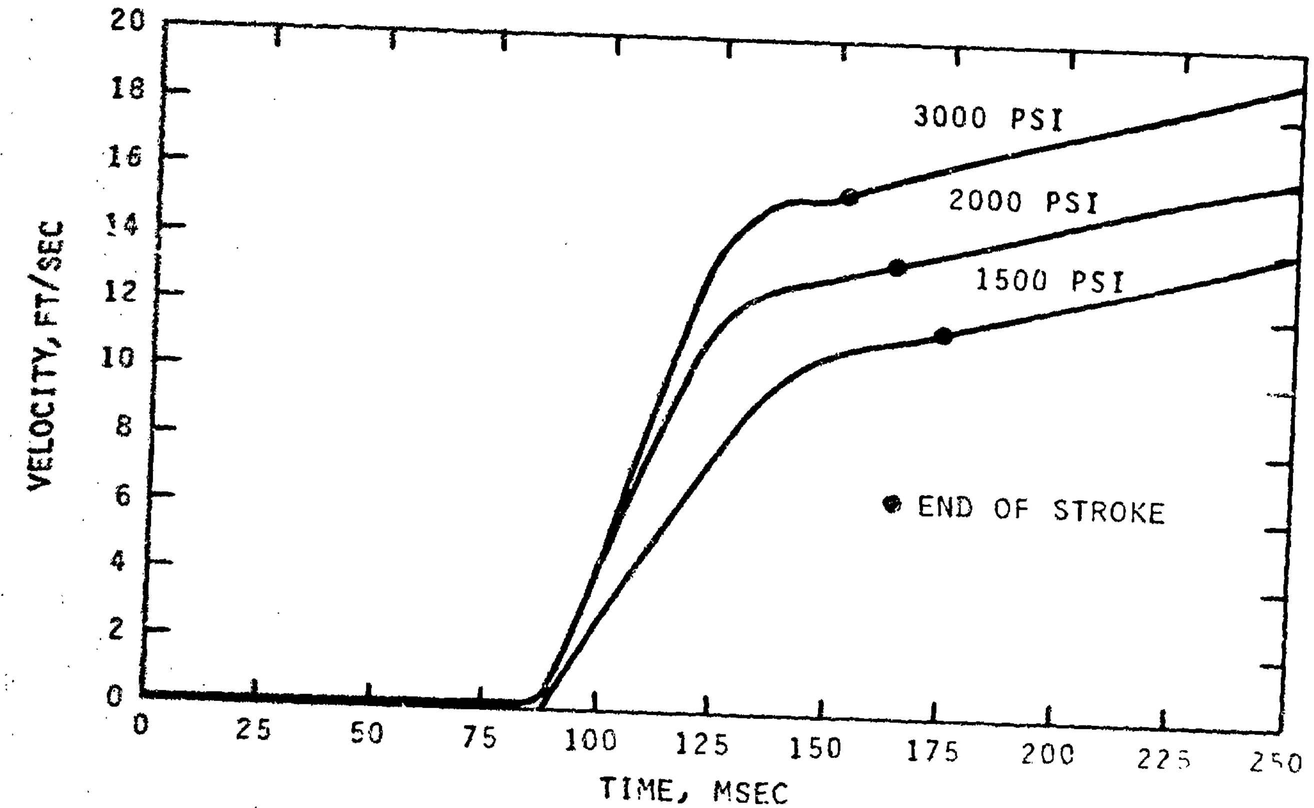


Figure 16. Ejection Velocity of Mk 82 Bomb (Conical Tail Fin).

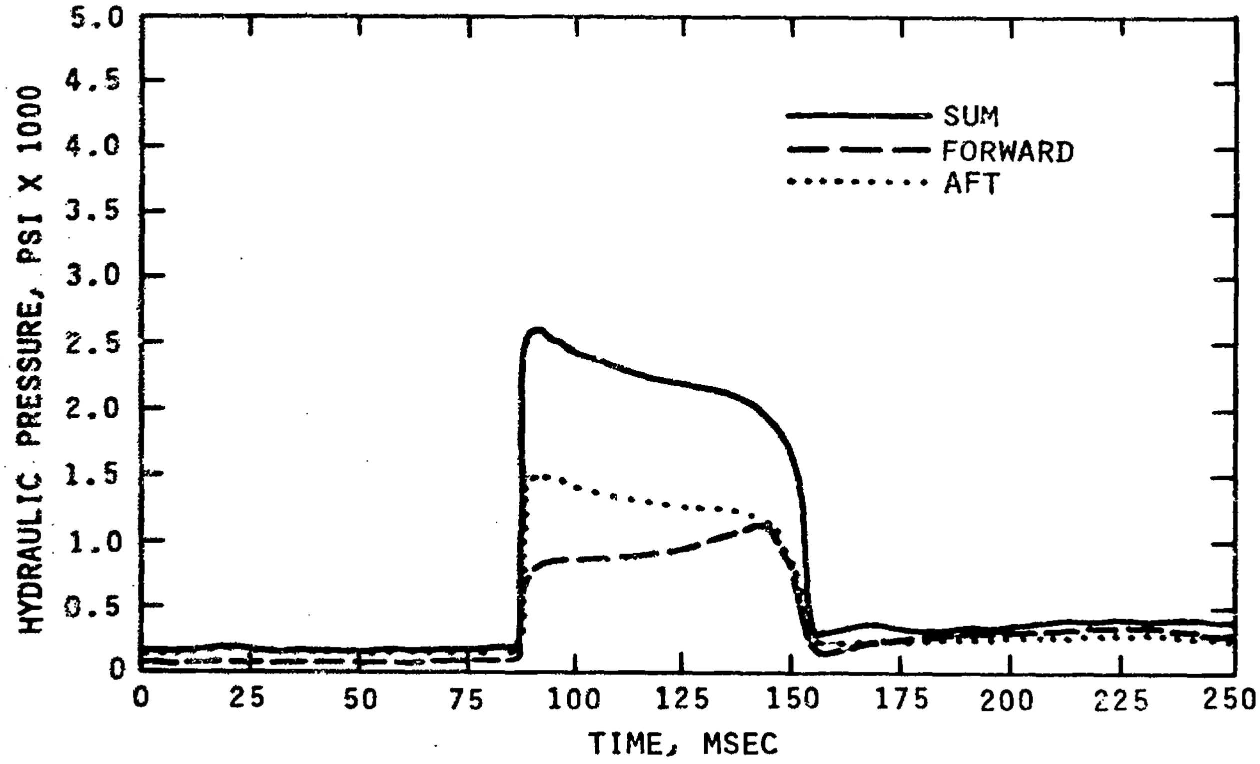


Figure 17. Forward and Aft Ejector Pressure Summation - 6/6 In. Strokes, 16,000 In./lbs Applied Nose Down Moment, 3000 PSI, Mk 82 Bomb.

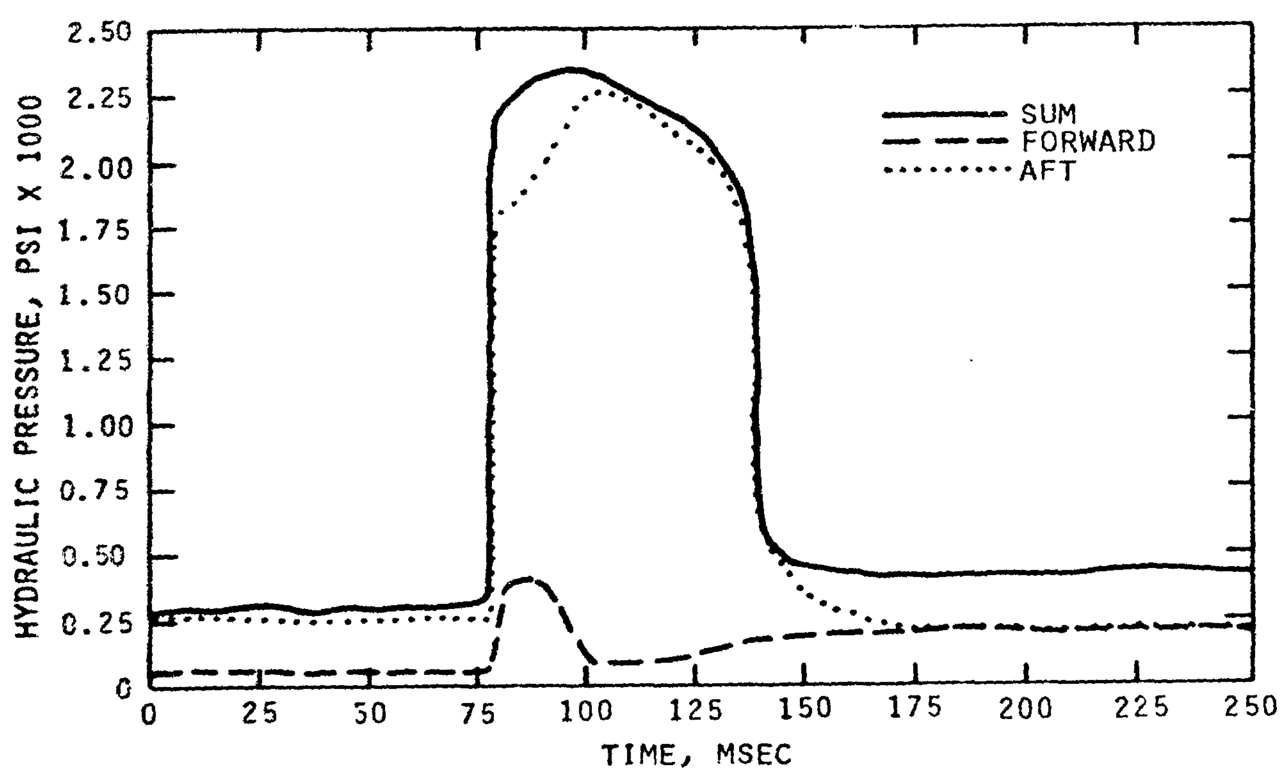


Figure 18, Forward and Aft Ejector Pressure Summation - 6/6 In. Strokes, 32,000 In./lbs Applied Nose Down Moment, 3000 PSI, Mk 82 Bomb.

total (sum of) pressure curves are the same for all ejections at 3000 psi. The pressure curves of the forward and aft piston assemblies (on Figure 17 and 18) show the automatic distribution of pressure to balance the external force. As more and more force is applied, the pressure is distributed to the aft piston until all the pressure is at the aft assembly with the 853 lb load applied.

Non-Parallel Ejection

The remainder of the tests were performed with stroke changes induced. The aft piston stroke was held constant at 6.0 inches while the forward piston assembly was reduced to 4.5 inches. The same external force was applied, as in the parallel ejection tests, to determine the effect on ejection performance. Figures 19 and 20 contain graphs of the pressure curves for 16,000 and 32,000 in./lbs applied nose down moment, respectively, showing the change in the forward and aft piston pressures while the total (sum of) pressure curves of each remain the same. The ejector system automatically compensates for the external load by balancing the pressures required for controlled ejection. Test data showed an attitude control capability of the test hardware of up to 32,000 in./lbs nose down moment at a GN_2 pressure of 3000 psi.

Acceleration and Velocity During Ejection

Acceleration and velocity data for the 3000 psi tests (with externally applied loads) are contained in Appendix C, Figures C-1 through C-4. The acceleration and velocity data were obtained from the recorded acceleration of the forward and aft accelerometers on the bomb.

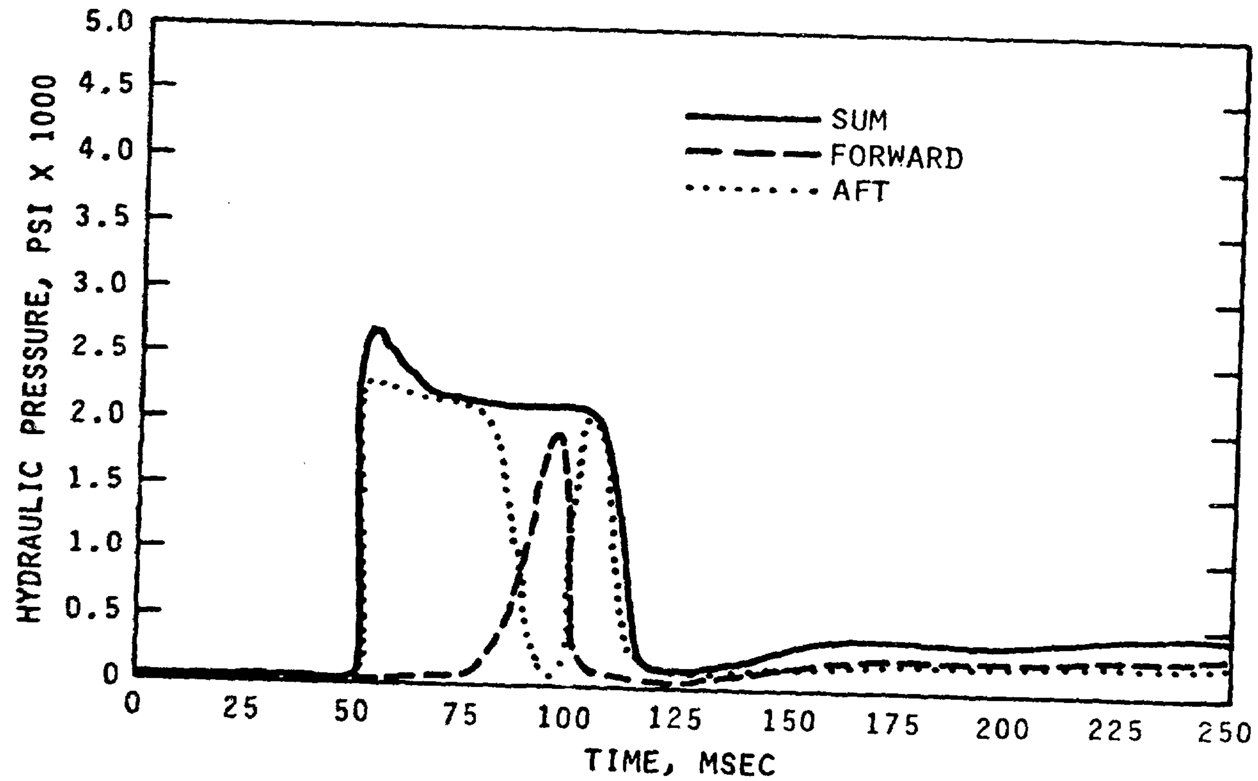


Figure 19. Forward and Aft Ejector Pressure Summation - 4.5/6 In. Strokes, 16,000 In./lbs Applied Nose Down Moment, 3000 PSI, Mk 82 Bomb.

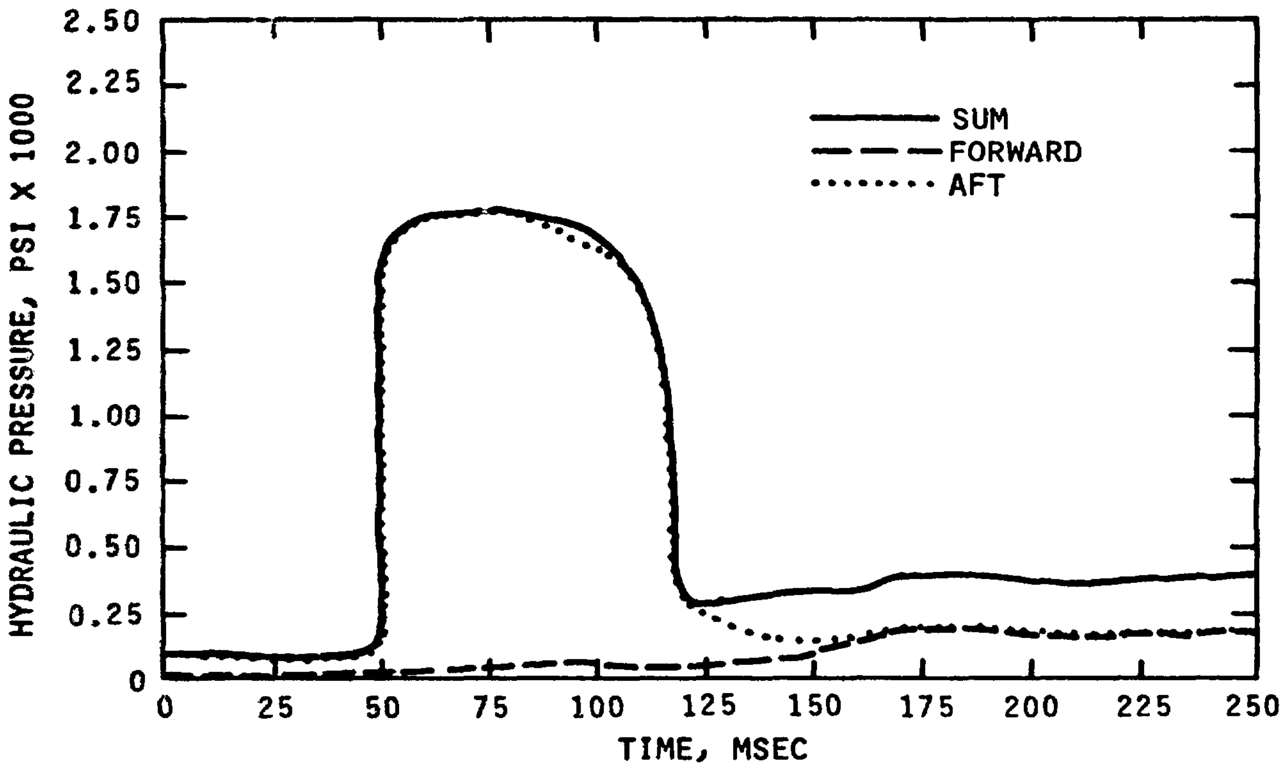


Figure 20. Forward and Aft Ejector Pressure Summation - 4.5//6 In. Strokes, 32,000 In./lbs Applied Nose Down Moment, 3000 PSI, Mk 82 Bomb.

SUMMARY AND CONCLUSIONS

The results of these first tests indicate the ejector system has the capability to provide parallel dependent ejection and to control the store in the pitch plane during the ejection cycle. With increased aircraft speeds, and the possible requirement for supersonic release of stores, it becomes apparent that pitch control of stores must be maintained throughout the ejection cycle. An ejector system with pitch control will expand the current release envelopes and still ensure safe separation of the weapon systems providing better compatibility with the performance of existing aircraft and the future generation of advanced aircraft. The use of hydraulics allows for flexibility in design of the ejector stroke length without significant increases in width, height or weight of the bomb rack. Current designs allow an ejector piston stroke extension of up to 11 inches. The capability of increased ejection stroke lengths and cold gas power systems will give more uniform store accelerations and will result in higher end of stroke velocities. The dependency characteristics will assure pitch control of the store throughout the ejection stroke. Given the requirement for ejection with changes in the pitch plane of the store, the ejector controls allow for pitch attitude change at end of stroke without pitch rate, or ejection of the store with induced pitch angular rate.

Ejector systems of this type will control the store pitch attitude independent of flow field forces and moments. Therefore, during the ejection stroke, the flow field forces are ineffective in perturbing the store in the pitch plane. The determination of the magnitudes and directions of these flow field forces throughout the aircraft flight envelopes is of major importance in enabling an adequate design of the ejector power system to balance these forces.

An added potential for this ejector system is the capability to measure ejector pressures (and thus, force/time) in each ejector assembly during ejection of the store. To date, the ability to determine what force, or forces are required to maintain the store parallel during ejection has not been demonstrated. This capability to measure the pressures as a function of time should be a useful tool to the aerodynamicist in analyzing flow field phenomena for a better understanding of the forces acting on the store during ejection.

By use of a cold gas power system the capability exists to control store ejection velocities by varying the ejection pressures as required for safe separation. This could be an automatic feature built into the aircraft fire control system. A pressure sensor and control valve could be used to reduce the ejection pressure so safe separation of the store could be maintained. For example, a fully loaded MER would be ejected with maximum ejector pressure. As stores are released, the primary ejection pressure would be adjusted to match the existing load on the MER until such time as the MER is empty. The adjusted pressure would be the correct ejection pressure for an empty MER rack. This automatic capability would allow ejection of various stores from the same ejector with the same ejector with the correct pressure for better ballistic separation.

Ultimately, a complete set of release parameters for each store could be stored within the aircraft computer. With the integration of the aircraft sensors to indicate status at any time during flight, the ejector stroke and ejection controls could be set automatically to match the release environment present at that instant.

The use of a cold gas power system is highly recommended and should reduce the overall maintenance requirements to depot level only. A cold gas system will eliminate or reduce the following problem areas of ejection systems currently in use:

1. Aeroelastic problems during ejection through the capability to adjust the ejection forces to match the store.

2. CAD radiation hazards in the aircraft/store environment.

3. Removal, replacement, cleaning requirements and performance variability of CADs.

Current and projected FY76/77 activities are to design flight weight hardware for environmental and operational testing. Future considerations are for self-contained cold gas power systems which utilize the aircraft hydraulic/pneumatic systems to recycle the ejector system to the pressurized condition after store release. A complete system design integrates other advanced armament elements such as stores management system, data and power interface system, automated sway bracing, and automated stores and station identification system.

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AUTOBIOGRAPHY

Mr. Panlaqui is a graduate of the University of Colorado with a Degree in Civil Engineering. At present, he is a Project Engineer in the Aircraft Armament Integration Branch at the Naval Weapons Center, China Lake. In this capacity he has been responsible for the suspension and release technology effort from 1973 through 1975. He served for 3 years on the panel of experts evaluating aircraft configurations for mechanical/electrical problems for the Naval Air Systems Command. Mr. Panlaqui has had 12 years experience in weapons development and structural design for test facilities. He has several patents in ordnance, fuzes and bomb rack components and is the co-inventor of this ejector system.

LLOYD J. HOLT
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AUTOBIOGRAPHY

Mr. Holt has had 33 years of experience in experimental aircraft design and aircraft related weapons programs. He has been with the Naval Weapons Center for 16 years working in Aircraft/Weapon Systems. During the past three years his efforts have been devoted to advanced technology developments in suspension and release equipment. Mr. Holt is the co-inventor of the Dual Ejector System and a holder of several patents and awards.

APPENDIX A

Appendix A contains a graphic presentation of simulated air loads (Figure A-1), showing applied moment and force, on a typical Mk 82 bomb which were externally induced for these tests. Also contained herein is a list of aircraft currently using Greene Tweed seals (TABLE A-I) and a complete listing of the dual ejector system test conditions (TABLE A-II).

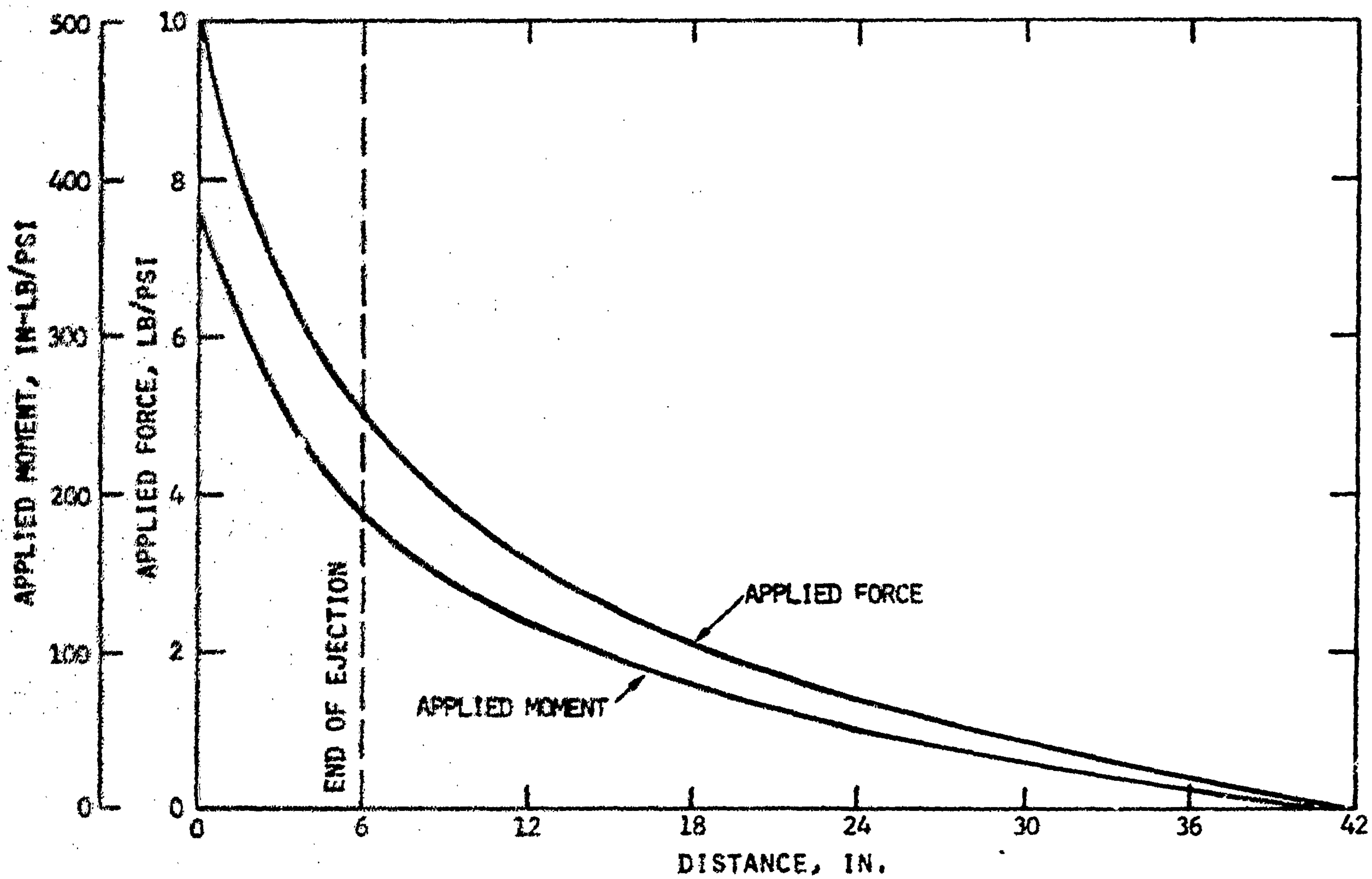

Figure A-1. Simulated Air Loads, Mk 82 Bomb.

Aircraft currently utilizing Greene Tweed Seals in landing gear shock strut systems are listed in Table A-I.

TABLE A-I. Aircraft Utilizing Greene Tweed Seals.

CIVIL

(Delivered by the manufacturer with Greene Tweed Seals.)

Boeing 727	Douglas DC-8	Lockheed L-1011
Boeing 737	Douglas DC-9	Concorde
Boeing 747	Douglas DC-10	A-300
		Mercure

MILITARY

A-7	C-5A	CH-3	F-4	T-2
A-10	C-7A	CH-53	F-8	T-38
A-37	C-123	CH-46	F-5	B-66
	C-130		F-14	S-3A
	KC-135		F-15	
	C-141		F-102	
	C-118		F-105	
			F-111	

Development Stage Military Aircraft

B-1
YF-16
YF-17
UTTAS and HLH helicopters

TABLE A-II. Dual Ejector Test Conditions

SERIES NO.	TEST NO.	EJECTION PRESSURE INITIAL	INCREMENT	FINAL	EJECTION STROKE FWD	AFT	FORCE	MOMENT
I	1-9	1000	250	3000	6.00	6.00	0	0
II	1-9	1000	250	3000	6.00	4.54	0	0
III	1-3	2000	500	3000	6.00	3.07	0	0
IV	1-3	2000	500	3000	6.00	6.00	427	-16K
V	1-3	2000	500	3000	6.00	6.00	853	-32K
VI	1-2	2500	500	3000	6.00	6.00	1280	-48K
VII	1-3	2000	500	3000	4.54	6.00	427	-16K
VIII	1-3	2000	500	3000	4.54	6.00	853	-32K
IX	1-2	2500	500	3000	4.54	6.00	1280	-48K
X	1-2	2500	500	3000	3.06	6.00	853	-32K
XI	1-2	2500	500	3000	3.06	6.00	1280	-48K

APPENDIX B

Appendix B contains acceleration and velocity curves (Figures B-1, B-2 and B-3) for 3000 psi ejection pressures with no external forces applied to the Mk 82 bomb. Acceleration and velocity data for ejector stroke lengths of 6.0 in. forward/ 6.0 in. aft, 6.0 in. forward/4.5 in. aft, and 6.0 in. forward/ 3.0 in. aft, respectively, are contained in these figures.

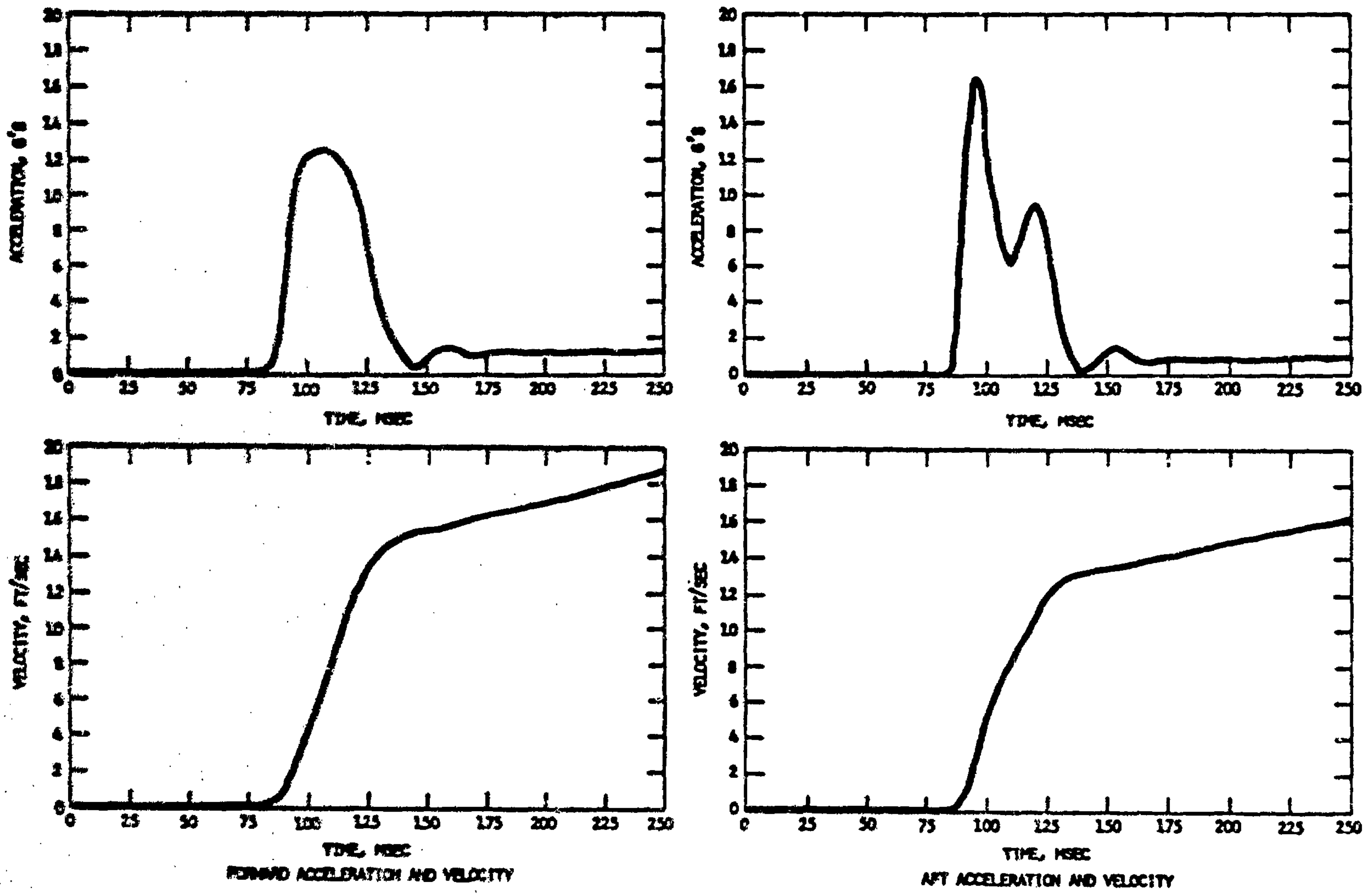

Figure B-1. Acceleration and Velocity - 6/6 In. Strokes, No External Force, 3000 PSI, Mk 82 Bomb.

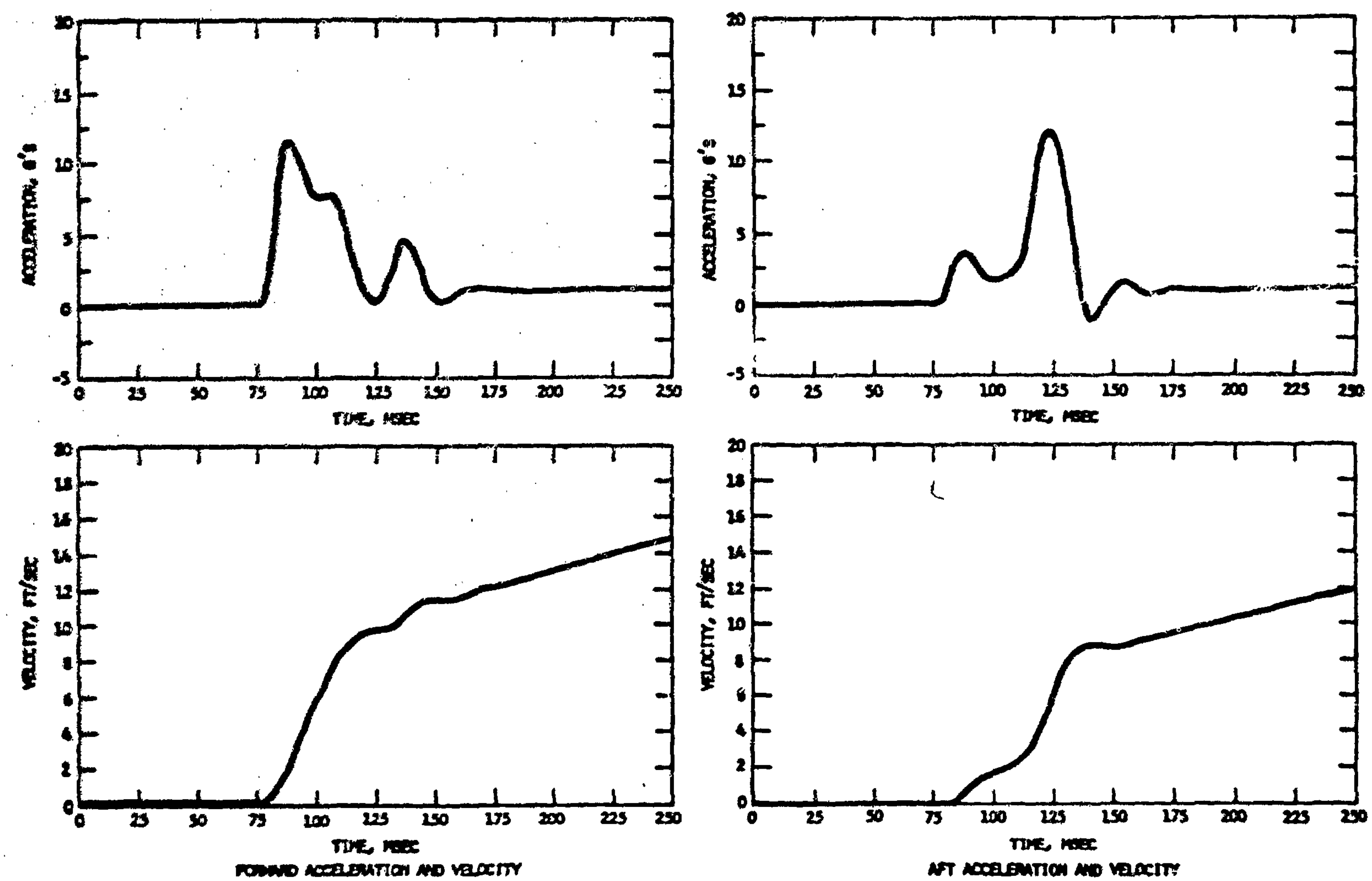

Figure B-2. Acceleration and Velocity - 6/4.5 In. Strokes, No External Force, 3000 PSI, Mk 82 Bomb.

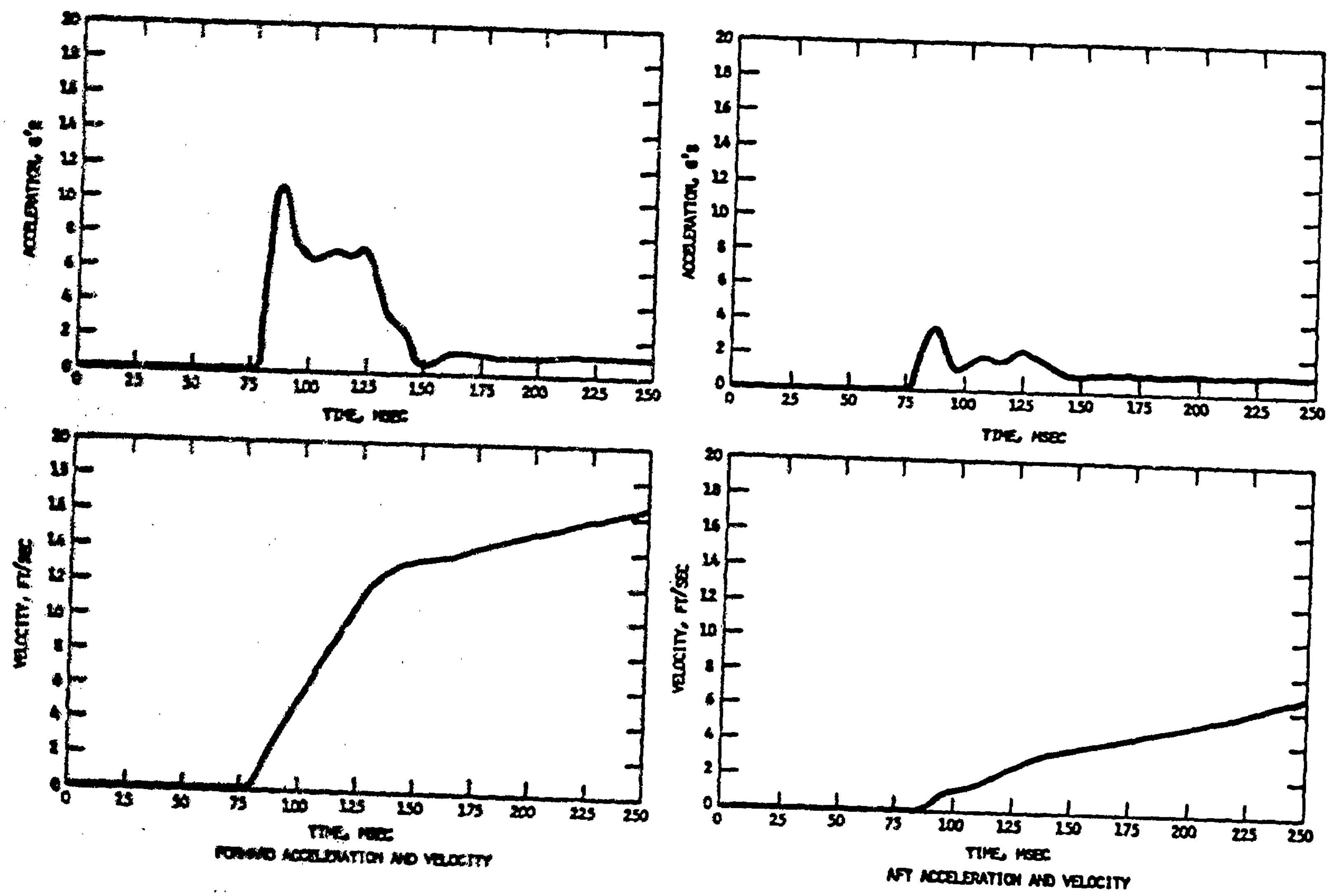

Figure B-3. Acceleration and Velocity - 6/3 In. Strokes, No External Force, 3000 PSI, Mk 82 Bomb.

APPENDIX C

Appendix C contains acceleration and velocity curves (Figures C-1 thru C-4) for 3000 psi ejection pressures with external simulated air loads applied to the Mk 82 bomb. Acceleration and velocity data for ejector stroke lengths of 6.0 in. forward/6.0 in. aft and 4.5 in. forward/6.0 in. aft, respectively, with externally applied nose down moment of 16,000 and 32,000 in./lbs are contained in these figures.

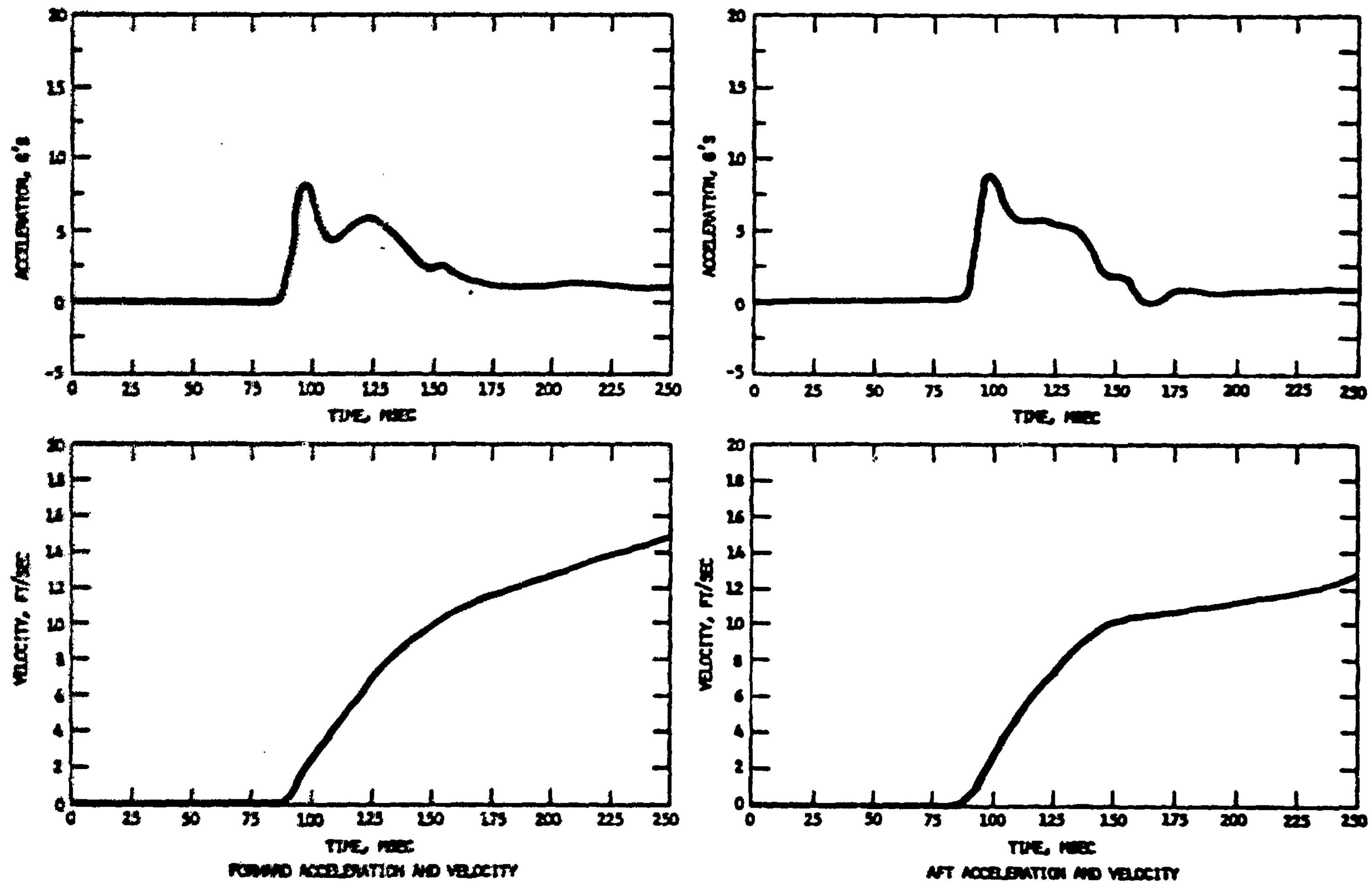

Figure C-1. Acceleration and Velocity - 6/6 In. Strokes, 16,000 In./lbs Applied Nose Down Moment, 3000 PSI, Mk 82 Bomb.

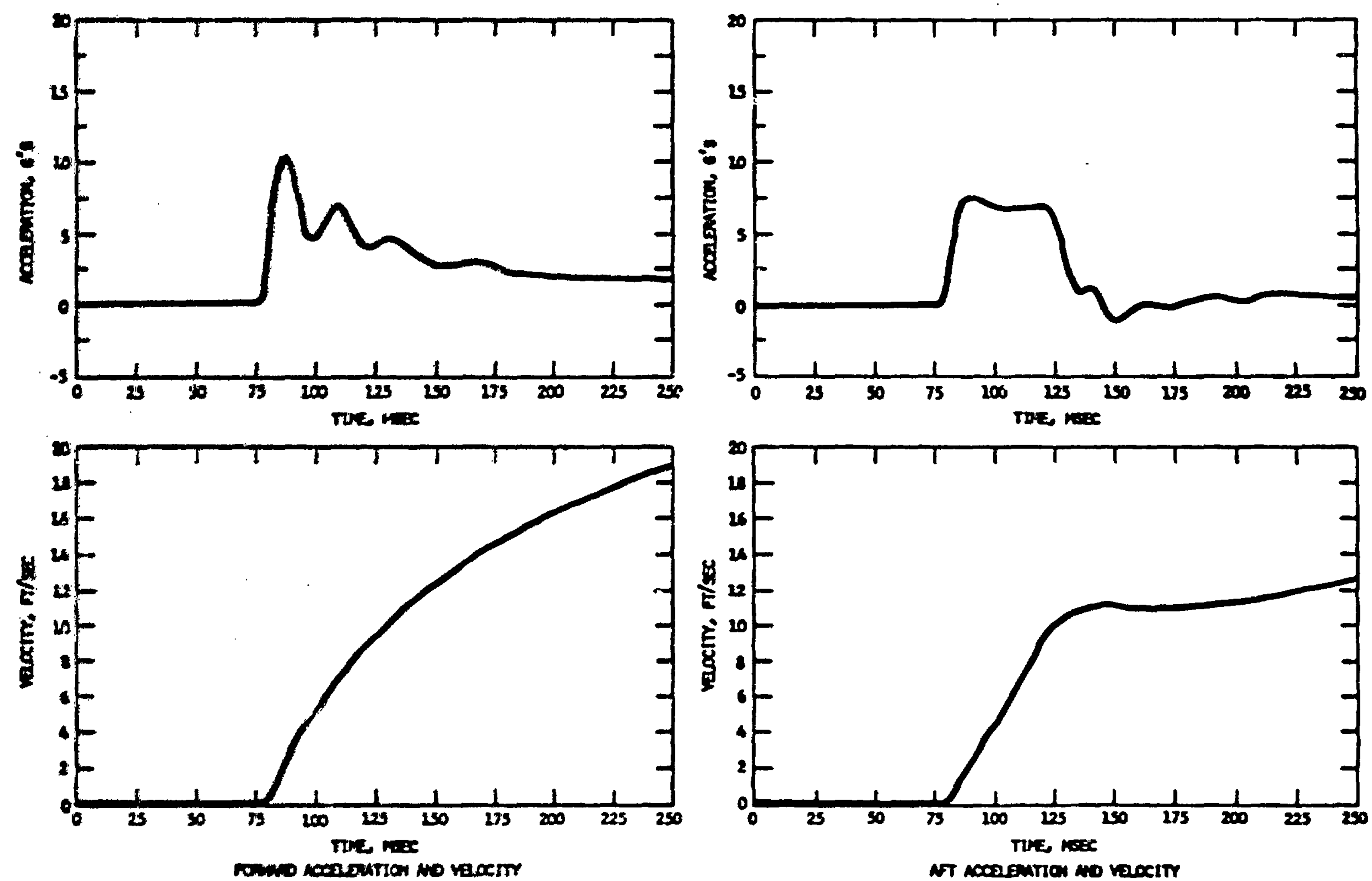

Figure C-2. Acceleration and Velocity - 6/6 In. Strokes, 32,000 In./lbs Applied Nose Down Moment, 3000 PSI, Mk 82 Bomb.

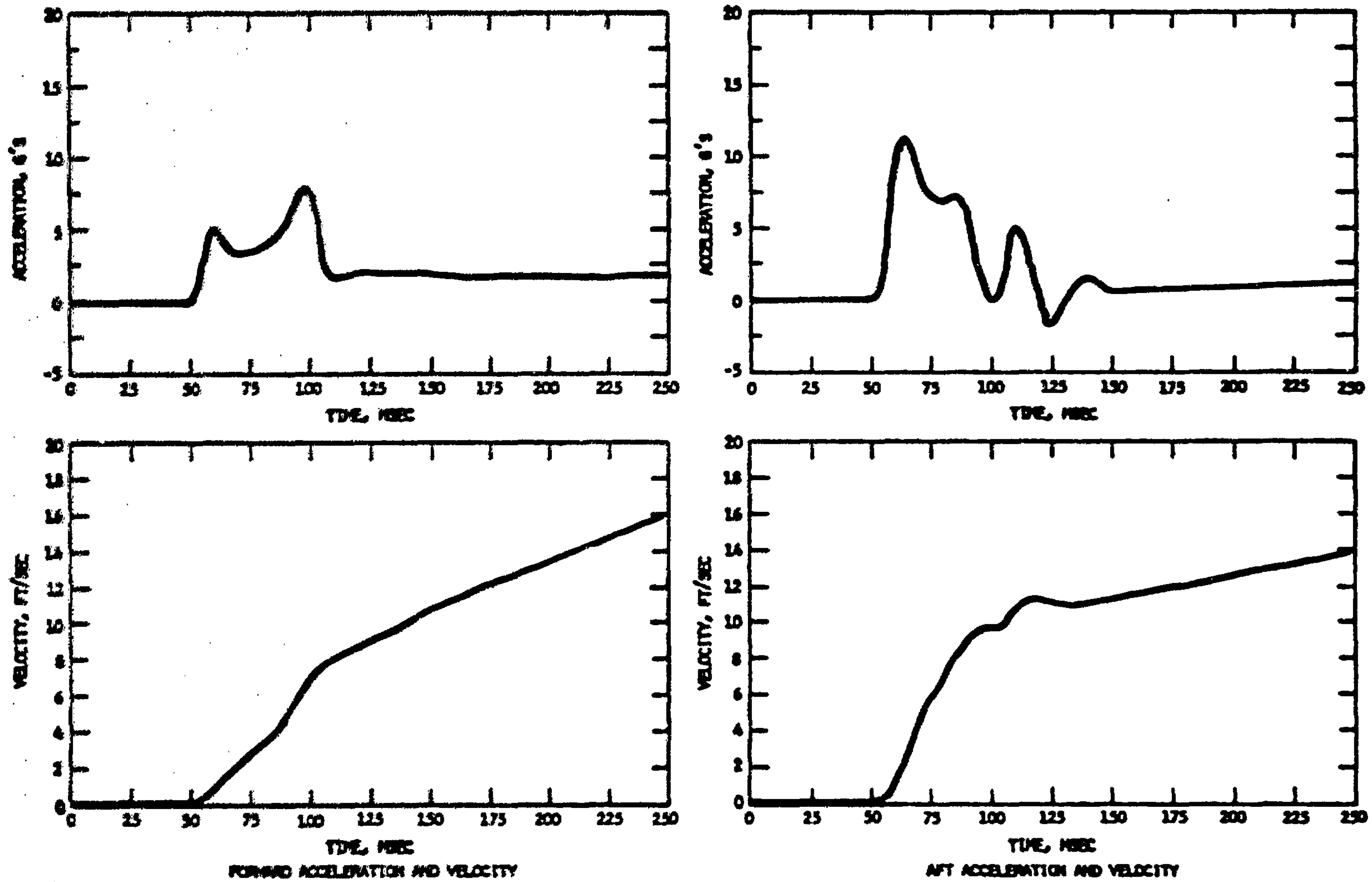

Figure C-3. Acceleration and Velocity - 4.5/6 In. Strokes, 16,000 In./lbs Applied Nose Down Moment, 3000 PSI, Mk 82 Bomb.

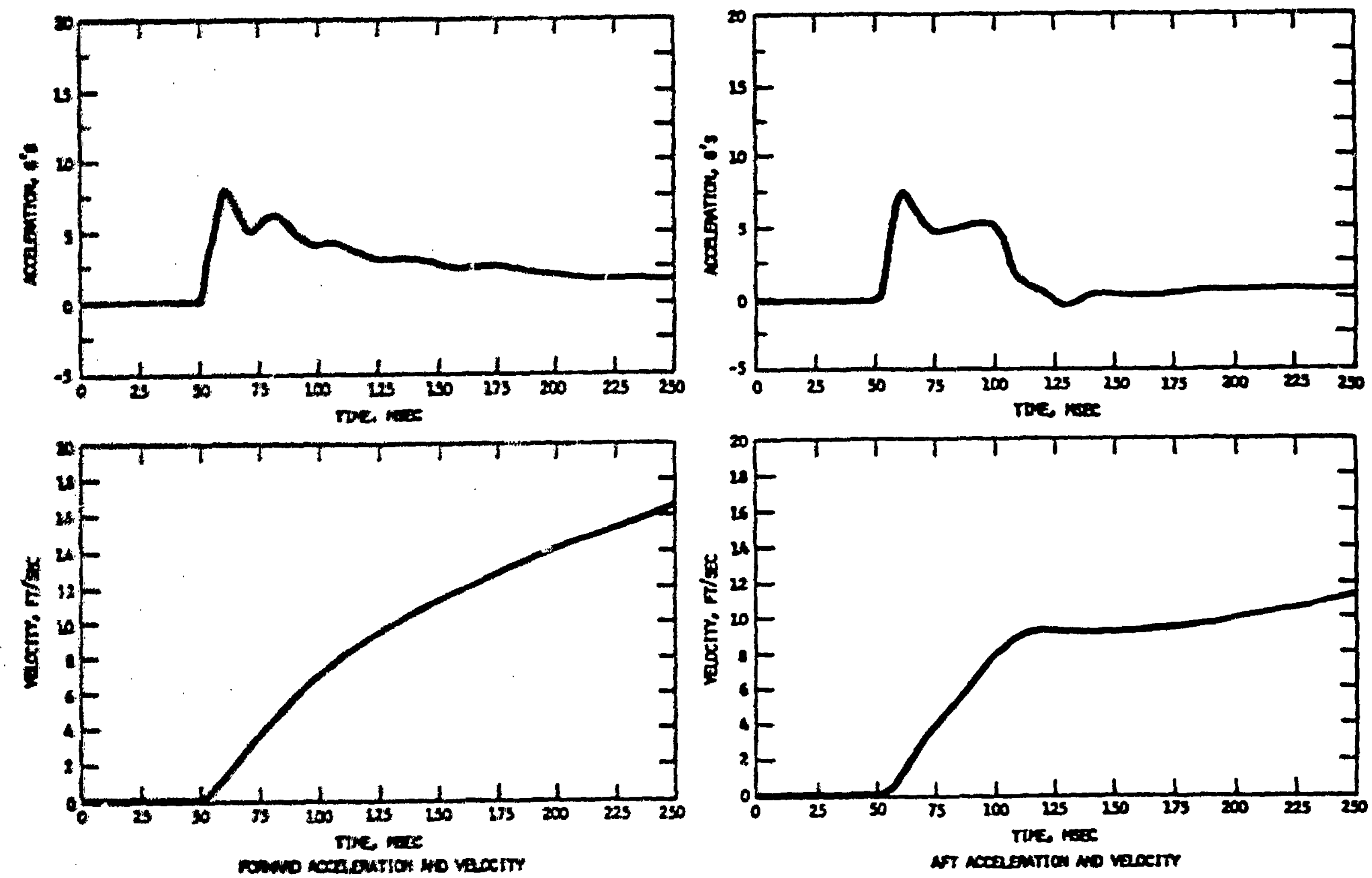

Figure C-4. Acceleration and Velocity - 4.5/6 In. Strokes, 32,000 In./lbs Applied Nose Down Moment, 3000 PSI, Mk 82 Bomb.

THE DEVELOPMENT OF A COMPACT HIGH STRENGTH
EJECTOR RELEASE UNIT FOR MRCA

(Article UNCLASSIFIED)

by

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ABSTRACT. (U) This paper describes the new high strength Ejector Release Unit, inappropriately named the Light Duty Ejector Release Unit, which has been designed and developed by Frazer-Nash Limited for use on the three nation Multi-Role Combat Aircraft (MRCA). The equipment is to be produced in quantity for the three nations by Sandall Precision Company Limited a subsidiary of Westland Aircraft Limited.

The new release equipment is a twin suspension, twin ram, cartridge operated ejector unit designed to suit stores having 14" pitch suspension lug pockets. It has a number of unique features born of the requirement to achieve carriage strength normally associated with Ejector Release Units of 30" pitch suspension.

The design features a crutchless system of store suspension derived from the Minimum Area Crutchless Ejector (MACE) developed by the Royal Aircraft Establishment at Farnborough over the last two years. The suspension is designed to suit saddle lugs to the new Stanag 3727 and embodies a twin lobed hook with a system of directly coupled sprung wedges which results in a very rigid store location.

In order to contain production costs and to achieve the required carriage strength a new castable maraging steel of extremely high strength was utilised for the ram cases and breeches.

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The properties of this cast material are very close to its wrought equivalent in terms of proof strength, elongation and reduction of area. These properties have made possible a compact design of 14" ERU capable of supporting a twin store carrier loaded with two 1000 lb stores attached to similar ERU's, and also to withstand the very high moments of load resulting from ejection of stores from this configuration.

Other distinctive features of this new ejector are it. gas operated retracting rams and the fully isolated and filtered firing circuits.

The retracting rams combined with the slim profile of the ERU engender minimum drag in pylon installations whilst the performance of the ERU is developed to impart better than 10' per sec. velocity to a store of 1200 lbs. mass from either U.K. or U.S.A. cartridges to Stanag 3556 under static conditions.

The paper describes the suspension system of the ERU and the benefits attributable to it.

LIST OF ILLUSTRATIONS

INTRODUCTION

The Light Duty Ejector Release Unit was designed and developed in response to the requirement of Panavia Aircraft for the carriage of stores on the Multi Role Combat Aircraft (MRCA) being built by the United Kingdom, West Germany and Italy.

The aim was to produce a 14" ERU capable of carrying a wide range of stores up to 1200 lb in weight and including a twin store carrier fitted with similar release units each loaded with 1000 lb bombs, approximately 2500 lbs in total. The carriage and release capability of the unit was to be such that no limitations were to be imposed on the flight envelope of the aircraft due to any limitations of the release unit itself.

Good reliability, minimum maintenance and an ejection performance marginally better than other conventional 14" release units were also required by the Panavia specification.

In conjunction with the high strength capability a philosophy of minimum drag was to be pursued. The latter requirement led to the choice of an Ejector Release Unit based on the principle of the Minimum Area Crutchless Ejector (MACE) developed in the U.K. by the Royal Aircraft Establishment.

The principle of the MACE system of store suspension is described in detail in this paper. The decision to adopt this principle gave impetus to the design and development of a new Stanag saddle lug (Stanag 3727) capable of withstanding the very high loads produced due to the compactness of the MACE suspension system.

The urgent need for the development of this new saddle lug was born of the requirement to carry a twin store carrier loaded with two 1000 lb stores on a 14" suspension ejector release unit. A capability which had not been possible before due to the limitations of the standard NATO bale lug normally fitted to stores with 14" pitch lug pockets, and also the limitations of the crutch arms of conventional 14" ejector release units.

This high strength capability of the MRCA 14" unit, which is unmatched by any other 14" unit either in Europe or the U.S.A., makes the term 'Light Duty' Ejector Release Unit seem inappropriate. The term was given by Panavia to differentiate between the 14" and the heavier 30" unit also being developed for MK A.

Development of both the new saddle lug and the ejector release unit is still continuing but sufficient work has been carried out to date to establish confidence that all the aims of the new weapon carriage system are going to be fully realised. The 14" variant of the saddle lug has now undergone a series of ultimate load tests and has been given flight clearance.

The Ejector Release Unit has now completed all its qualification tests and the start of flight testing is now imminent. A similar unit, designated the ERU 123, developed for the United Kingdom Ministry of Defence has already been extensively flown to study the carriage and release characteristics of the MACE principle. The results of these tests confirm both the reduction of drag with consequent increase in range and reduced turn round time by elimination of crutch pad adjustments.

GENERAL DESCRIPTION

The Light Duty Ejector Release Unit is a twin ram, twin cartridge ejector release unit capable of carrying most stores with 14 inch pitch standard NATO lug pockets and conforming to the general requirements of MIL STD 8591E.

The unit utilises a conventional overcentre geometric locking system to operate the hooks and maintain them in either the open or closed attitude by means of a spring plunger reacting on the central toggle lever arm (see Fig. 2).

The gas system comprises the breech, which is situated centrally within the ERU, two gas pipes leading to forward and aft ram cases which house the throttle facilities and the retracting rams.

The breech, designed to accept cartridges conforming to Stanag 3556, e.g. the U.K. 201 Mk 1 or the U.S.A.F. ARD863/1, also embodies an actuator piston which, on firing, reacts on the central toggle lever to open the hooks.

The gas circuit includes end bursting cartridges and coarse filtration at the cartridge holder to limit the possibility of blocking a throttle due to cartridge debris (see Fig. 3).

The throttles are simple cylindrical components with a drilled crosshole embodying a molybdenum insert to resist erosion. These assemblies are inserted into a transverse hole in the ram case which intercepts the drill-way forming the gas path to the ram cylinder. The throttles are retained in angular alignment by a key and keyway and locked in by means of a ball detent. The throttles can thus be inserted or removed by one motion using a special bayonetted tool which automatically releases the ball detent.

The throttles do not have seals. The close fit of the throttle body in the ram case provide sufficient sealing and makes for minimum maintenance.

Three standard sizes of throttle orifice cover the full range of stores proposed. Orifice size is selected for fore and aft throttles to suit store mass, c.g. polar inertia and aerodynamics and to give clean ejection at maximum velocity consistent with limiting the reaction to suit aircraft structural constraints. A single variable throttle, preset before take off, is currently being designed and developed.

Mounted above the breech is a cast box embodying the firing circuits. The circuits include the usual rad. haz.filters and also as an option a relay isolation circuit designed to give absolute protection from imported induced electrical transients. The arrangement of the relays also provides additional safety such that firing pulses must occur on two lines simultaneously to ignite either cartridge. Each cartridge has an entirely separated electrical firing circuit but in the event of only one cartridge being electrically initiated, sympathetic ignition of the other cartridge occurs due to the breech chambers being interconnected.

Three microswitches operated by the hook overcentre mechanism serve as fusing supply breaks, store on station indication and firing circuit breaks. These switches will eventually be replaced by a new slide switch being developed for the U.K. Ministry of Defence to improve the reliability of the switched circuits and provide a fail safe feature.

The ram case assemblies embody the major load carrying components associated with the MACE principle of store suspension which comprise a forked hook, a pair of wedges mechanically linked to the hook and a spigot for reacting axial, side and yaw loads.

Although the overall space envelope is similar to other 14" ERU's (see Fig. 4) it is worth re-mentioning here that this unusually strong 14" unit is capable of carrying 2500 lbs in the form of a loaded twin store carrier (T.S.C.) and also capable of reacting the resultant 17000 lbs ft moment on the suspension system during the ejection of one store from the T.S.C. This high strength capability is met within an envelope of only 50mm (1.96 inches) wide except for the hook and the ram case wedge housings which are only 80mm (3.15 inches) wide.

THE MACE SUSPENSION SYSTEM

PHILOSOPHY

For many years studies have been made to examine what improvements can be made to reduce the drag and other deleterious effects of weapon carriage and release systems.

Aircraft designers, who above all are conscious of the need to maintain low drag profiles to optimise range and performance as well as to reduce operating costs, are very familiar with the drag penalty attributable to the crutch arm protubarances of conventional weapon release units.

With this in mind, and also the ever present need to reduce operational turn round time and ground crew team size, the principle of MACE (Minimum Area Crutchless Ejector) was developed by the Royal Aircraft Establishment at Farnborough, U.K.

The MACE principle recognises the fact that there are in existence large quantities of aircraft munitions designed to be carried by conventional crutched ERU's, and that these are not likely to be replaced for many years. The MACE concept therefore was designed to be applied to existing stores through the substitution of the conventional bale lug for a Saddle Adaptor lug.

DESCRIPTION OF OPERATION

SADDLE LUG

To suit the MACE philosophy of suspension it was necessary to design and develop the new saddle adaptor lug shown on Figure 5. The special saddle lug which has recently received recognition as a NATO STANAG (STANAG 3727) is fitted to stores by means of a securing ring.

The underside of the saddle is shaped to suit a variety of store diameters or profiles and is pre-tensioned to it by torque tightening of the securing ring into the existing threaded lug pocket. The innermost faces of the saddle lugs have two profiled recesses to accept the ejector hooks which have corresponding twin tapered projections (nibs). Nearly all existing stores to NATO agreed standards may be adapted in this simple manner for operation with MACE type ejectors.

EJECTOR SUSPENSION SYSTEM

The components of the ejector release unit which are specifically designed for the MACE carriage system are shown in Figure 6 and comprise a very high strength hook, a pair of sliding wedges to react vertical upward forces due to pitching and rolling moments and a spigot which engages with a central recess within the saddle lug screwed ring to react the side and yaw loads. All these components are assembled to the ram case which also embodies the mounting holes for the pylon attachment bolts.

The hook is designed with twin protuberances which are a close fit within the saddle lug recesses. The hook is pivoted from the ram case by a hollow fulcrum sleeve which also provides one of the attachment bolt holes to the pylon. Hook loads are thus transferred as directly as possible into the pylon making for maximum load transmissability and stiffness.

The wedges are loosely contained within inclined slideways machined into buttresses on either side of the ram case. They are also mechanically attached to the hooks by means of connecting rods which have limited axial movement through holes machined into lugs projecting from the sides of the hooks. A compression spring, coaxial with the rod between the hook lug and the wedge, provides the means of automatically driving the wedge forward into contact with the top surface of saddle lug on cocking.

The spigots are deeply recessed into the underside of the ram case into which they are screwed and locked by means of a grub screw.

In operation the movement and locking of the hooks is by means of the over-centre toggle mechanism (see Fig. 7). The wedges, being mechanically linked to the jaw are constrained to move with it when uncocked but free to slide sufficiently to obviate clearance between the saddle lug and wedge lower profile when cocked. This arrangement is designed to guarantee that under icing or other conditions likely to inhibit movement, the wedges are forcibly withdrawn as the hooks open to ensure the necessary overtravel clearance for subsequent bombing up operations. It will be apparent from Figure 7 that on loading the store the act of closing the jaws produces a spring load on the wedges which causes them to move in and take up all available clearance between the ram case and the saddle. This feature gives good rigidity during carriage and obviates the need for crutch arms with the four crutching screws. Store loading time is therefore minimised as with one motion the ejector is both cocked and crutched.

The lower surface of the wedge is profiled with a slight curve to ensure that the point of contact with the saddle lug is predictable and compensates for any angular mis-alignment of the lug that might otherwise upset the operation of the wedge.

During flight it is important that the wedge does not move out of engagement with the saddle lug as the compressive load increases. Conversely it is also important that the unloaded wedge during a rolling load should not become so deeply engaged that the subsequent manual un-cocking to remove a non-released store is difficult. These criteria are satisfied by the careful choice of wedge angle, surface finishes and spring load and much experimentation has been carried out at RAE Farnborough to this purpose.

LOAD PATH

The difference in load path between a crutched and crutchless ejector is illustrated in Fig. 8.

In the case of a conventional crutched unit a direct side load generated by aerodynamic and inertia loads on a store is reacted on projections from the ram case forging which abut the side of the bale lug. The moment due to the offset of this load produces a downward load on the hook and an upward load on the crutch arm pad on the relevant side of the unit.

In the case of the MACE unit the direct side load is reacted by the spigot engaging within the saddle lug securing ring (see Fig. 9). The downward component due to the resultant moment is reacted through one of the hook nibs and the upward load through the opposite wedge. It will be seen that the distance between the reaction points on the crutched and crutchless ejectors are not very dissimilar, so that reaction loads are not significantly higher on the MACE unit for a given applied moment. It is apparent, therefore, that the overall strength and stiffness as well as the frontal area effect of the crutchless system are superior to the more conventional unit. In fact the maximum width of the MACE unit at the wedge housings is no more than the width of a typical pylon into which it may be fitted.

The significance of the load carrying capability of the MRCA light duty ejector unit has already been mentioned and is amply demonstrated by the fact that it is proposed to carry a twin store carrier loaded with two 1000 lb bombs mounted on identical ERU's. (See Fig. 10). The ERU is to sustain not only the full carriage loads due to this configuration but also, more significantly, the severe moments that derive from the ejection of one of the two bombs (see Fig. 11).

The maximum thrust of the ejector units is 10,000 lbs and it will therefore be appreciated that the moments to be reacted by the jaws and wedges of the unit supporting the twin store carrier are extremely high and are in the order of 17,000 lbs ft. This moment results in reactions on one hook nib and a wedge in the order of 45,000 lbs.

To the knowledge of the author, no other 14" ejector release unit either in Europe or USA has this strength capability. It has always been previous practice to support such carriers from 30" suspension units. Certainly no other crutched type 14" ERU can approach this strength without there being a spigot between the T.S.C. and the pylon to react the high moment loads. The strength of conventional ERU's is also limited due to the strength of the standard NATO bale lug which is designed for 1000 lb class stores only i.e. for stores up to 1,450 lbs weight, whereas the load carrying capability of the MRCA crutchless unit is due to the development by the RAE in UK of the new saddle type suspension lug for 14" centres which is capable of carrying stores up to 2500 lbs.

RETRACTING RAMS

In keeping with the minimum drag philosophy it was logical that automatic retracting rams (see Fig. 12 should

be specified for this ERU and of the two alternative modes of retracting ram, i.e. spring return or gas return, gas was chosen because:-

a. It avoids the difficulty of having to hook up the spring to the top of the ram case bore, a problem which is extremely difficult to overcome when removing pistons for cleaning from an ERU situated in the aircraft pylon.

b. It avoids the need to provide elaborate erosion protection for the spring.

c. It enables a piston to be designed with a solid head thus minimising the internal volume of the ERU and reducing adiabatic and other conducted losses.

d. It provides, when properly valved, a significantly larger retracting force than a spring.

The retracting ram illustrated comprises a hollow piston with an axial pintle valve which is free to slide through bores at the head and base of the piston.

The piston is fitted with two conventional piston rings and just under the piston head a small hole is drilled radially to connect the annular area under the head with the hollow centre of the piston.

The pintle valve consists of a tube open at both ends which has a small hole drilled radially through the tube wall near the bottom and an enlarged diameter near the top forming a valve seat.

When assembled the pintle valve is retained by a screwed ring which locates in the bottom of the piston and the pintle then has a limited axial travel. At the top of this travel the valve is so arranged as to seal the hole under the piston head, and at the bottom of its travel the radial hole at the bottom of the pintle tube is sealed off by the bore of the screwed retaining ring.

The principle of operation is as follows:-

When the cartridges are ignited, gasses pass through the throttle into the ram case and the piston and pintle valve are forced hard down onto the surface of the store. Contact with the store effectively closes off the pintle valve to atmosphere so that gases passing down the centre of the valve from over the piston head are diverted, through the drillway, into the hollow centre of the piston which serves as an accumulator.

The accumulator charges up continuously throughout the stroke of the ram until on reaching the end of stroke the ram is arrested. The pintle continues until it reaches the end of its travel and separates from the store. At this point the residual gas above the piston is vented to atmosphere through the pintle valve, the drillway into the accumulator is sealed off by the bore of the screwed retaining ring, and the drillway under the piston head is exposed so that the accumulated gas in the body of the piston is vented to the annular area under the piston head.

As the residual gas vents to atmosphere the piston retracts sharply when the ratio of pressures under and above the piston head exceeds the ratio of areas.

Retraction forces of 200 lbs are consistently achieved by this means which it is calculated should be sufficient to overcome possible stiction caused by the aerodynamic drag on the extended piston.

MARAGING CASTINGS

The need to keep weight to a minimum and yet maintain production costs to an acceptable level led to the adoption of a cast maraging material for the more complex and highly stressed components in preference to a forging.

This cast maraging material could easily be the subject of a separate paper but is worthy of mention here because of the benefits derived from its use.

The material is a Normalair Garrett proprietary specification designated NGMS800. It has been approved by the U.K. Quality Assurance Authorities as an aircraft steel and is currently being indexed in the U.K. D.T.D. aircraft standards.

The chemical composition is based largely on the specifications for wrought maraging materials where Nickel, Cobalt, Molybdenum are the primary alloying constituents. However, modifications to the composition are made to improve the retention of properties on casting through the double vacuum process.

This material was used for the ram cases, the breeches and the toggle lever with success and after heat treatment typical physical properties of the material are:

Tensile Strength	113 Tons/sq. ins.
0.2% Proof Strength	104 Tons/sq. ins.
Elongation	8%
Reduction of Area	40%

No adverse effects from gas erosion or corrosion caused by cartridge ignition and the products of combustion have been observed through 600 firings, 315 of which were carried out on one ERU.

The material has been amply demonstrated as a suitable material for this application where very high strength combined with resistance to corrosion and erosion are of paramount importance.

To date there is no reason to doubt that the fatigue capabilities of the material will not be comparable with its wrought equivalent though work is still continuing on this aspect.

The overall saving in machining of these components compared with machining a forging is very significant as the lost wax process by which these castings are produced can achieve minimum material conditions and very close tolerances in the as cast condition.

So successful is this material and process in containing costs that there is a current investigation into the possibility of producing saddle lugs by the same means.

PERFORMANCE

This ERU has consistently achieved 11 ft/sec ejection velocity for a store mass of 1200 lbs from a test rig under static ambient conditions and within a reaction limitation of 10,000 lbs. Within the same reaction limitation and under similar test circumstances a plot of ejection velocity against store mass with variation due to temperature is shown in Fig. 13.

SERVICING

During the 600 firing test carried out on firing rigs it has been proven that using the U.K. cartridges No. 201 Mk 1 the unit will withstand a total of 50 firings at all temperatures without being removed from the pylon for cleaning.

Removal from the pylon for routine servicing is recommended after 30 days following any one firing or 6 months if the ERU has not been fired.

FLIGHT PERFORMANCE

Although no flight tests have yet been carried out on THE MRCA, R.A.E. have flight tested a MACE type ERU on a Buccaneer and have data indicating a very significant reduction in drag compared with a crutched ERU. From this data has been calculated the increase in range that would derive from the fitment of this ERU to other U.K. aircraft as well as the MRCA.

From the wind tunnel tests by R.A.E. it has been shown that the removal of crutch arms produces a change in drag co-efficient equal to 0.06 which compares with the zero lift drag coefficient of a bomb in isolation of 0.09 at Mach 0.8. These experiments were conducted on a pylon/bomb combination only.

The flight tests conducted by R.A.E. have further shown that stores carried on MACE units experience less vibration and flutter than is experienced with conventional carriage. Some provisional figures indicate 50% reduction in vibration levels measured on an instrumented store.

MANPOWER SAVING

With MACE units there are less manhours expended when loading stores to carriers and carriers to aircraft due to the elimination of the need to slacken-off, torque tighten, and lock crutching screws.

An assessment by the RAF Central Servicing Development Establishment indicates that there is an 11% manhour saving when loading stores to twin carriers and a 22% manhour saving when loading stores or twin carriers to the aircraft. This saving should result in an overall reduction of first line armourers.

DEVELOPMENT TESTING

During evaluation and qualification over 600 firings have been performed on the purpose designed test rig at the Frazer-Nash facility at Kingston upon Thames.

These monitored firings have been performed at temperatures ranging from -40°C to +120°C at the breech and with simulated stores ranging from 106 lbs to 1210 lbs.

The test rig is illustrated in Fig. 14 and comprises a portal frame mounted to a reinforced concrete foundation.

Two mounting stations are provided each with a dummy pylon attached to a sub-frame which is suspended from the rig portal frame by four load cells. The electrical outputs from the load cells are integrated to give reaction indication during ejection.

One mounting station is equipped with thermal facilities to direct hot or cold air at the pylon area by electrical resistance heaters and sublimation of liquid carbon dioxide.

The stores used on this test facility are slab weights which can be adjusted to represent differing mass, centre of gravity and pitch moment of inertia. In this way a variety of stores can be represented with ease.

The instrumentation associated with the rig includes pressure transducers to measure the pressure at the breech, ram case above and below the piston, load cells to measure reaction, timing devices to give the velocity at each end of the store and thermocouples to measure breech and ambient temperatures.

Hydraulic rams are provided to react between the main portal frame and the store to provide simulation of flight loads during ejection.

A foam lined pit is provided to arrest the store after ejection.

The firing pulses are provided through a purpose made pulse generator simulating the aircraft electrics with variable pulse width and amplitude.

All the instrumentation is connected to an on line computer which, on demand, initiates the firing sequence and stores all data pertaining to pressures, reactions and velocities as well as event marking such as times for hooks to open.

The computer gives an immediate digital readout picking of peaks of pressures and reactions as well as computing store velocity at c.g. and pitch rate. On demand the computer will also produce X-Y plots of pressures and reactions.

CONCLUSIONS

The concept of the Minimum Area Crutchless Ejector has wide application for the external carriage of stores on high performance aircraft. Its slimness and high tensile strength offers considerable improvements in aircraft range or performance while permitting stores to be carried through an extended flight envelope when compared with conventional crutched ERU's.

The MRCA Light Duty ERU has a strength capability up to 3 times better than existing crutched ERU's and also reduces the amount of vibration and flutter due to its superior stiffness.

There are further significant advantages in reduced turn round time and the manpower requirement to load stores or carriers to the aircraft.

The ERU has now completed its development testing with considerable success and further development work is being considered for other installation on other aircraft.

For the future it is envisaged that new stores may be designed with the MACE concept in mind and would include integral lugs for minimum drag, though no difference in drag has been recorded when comparing saddle lugs with conventional bale lugs on test.

The ERU itself may be further enhanced by the adoption of automatic latching, which should reduce the turn round time even further, and variations on mounting hole positions may be considered for specific retro-fit applications.

REFERENCES

1. RAE Memo. Notes on 'MACE' Type Release Unit Minimum Area Crutchless Equipment. Reference LSW/863/017/CN 8th February 1973.

AUTOBIOGRAPHY

B. HISCOCK. DIRECTOR AND TECHNICAL MANAGER

Mr. Hiscock joined Frazer-Nash Limited in 1960 to participate in the widely diverse engineering projects undertaken by the Company most of which were U.K. Ministry contracts for military and associated equipment.

In 1963 he was assigned the responsibility of the design and development testing of three very substantial ejector release units for the TSR2 low level attack aircraft. The assignment included participation in the development of cartridges for these Ejector Release Units in order to achieve optimum burning characteristics associated with the large internal volume and long stroke (22 ins) rams for TSR2 bomb bay application.

Having been assigned a number of unrelated but sophisticated engineering projects in the meantime, Mr. Hiscock was recently appointed Technical Manager (and subsequently Director) and given the responsibility for the complete design and development of the MRCA Light Duty Ejector Release Unit.

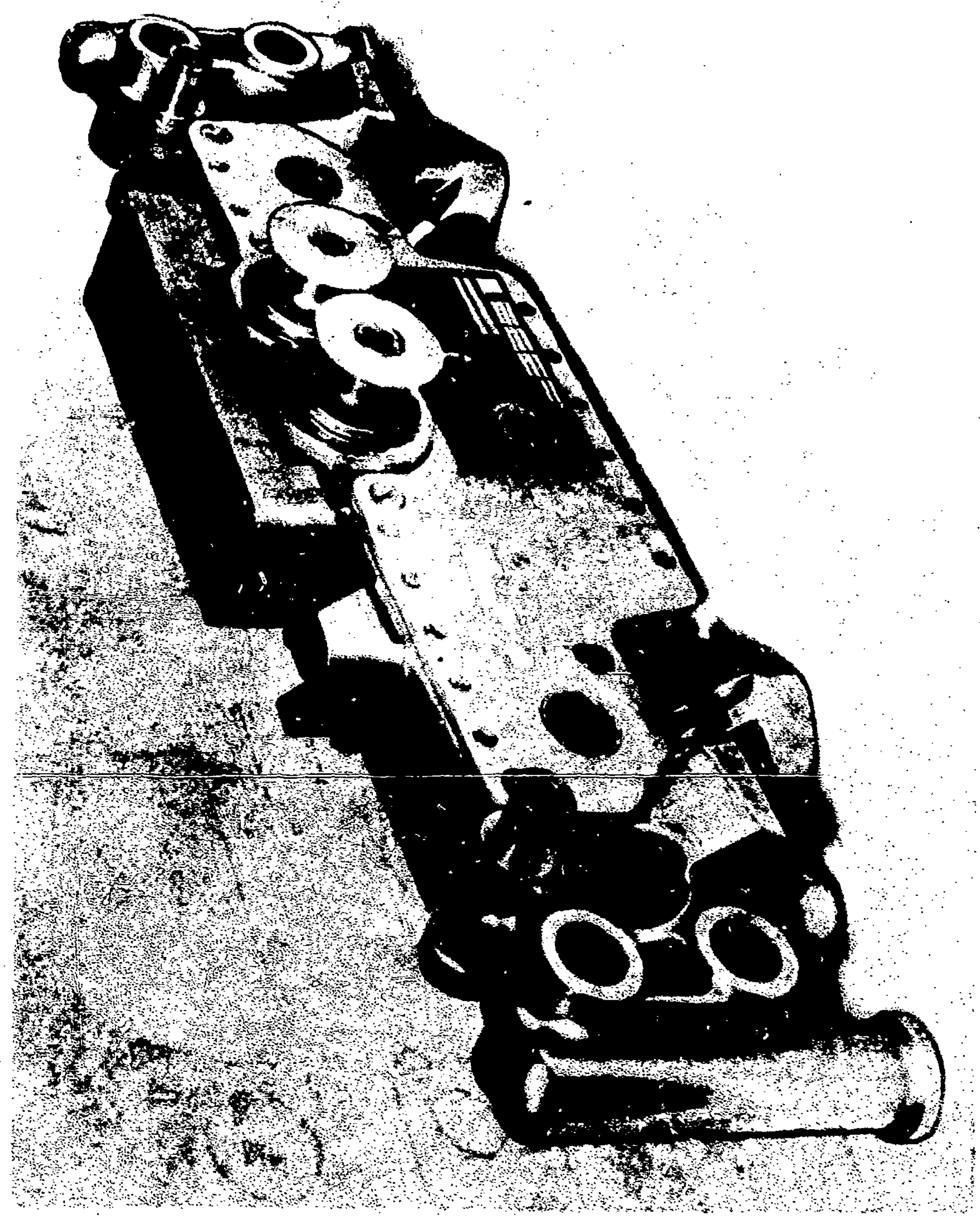

FIGURE 1 GENERAL VIEW OF 14" LIGHT DUTY E.R.U.

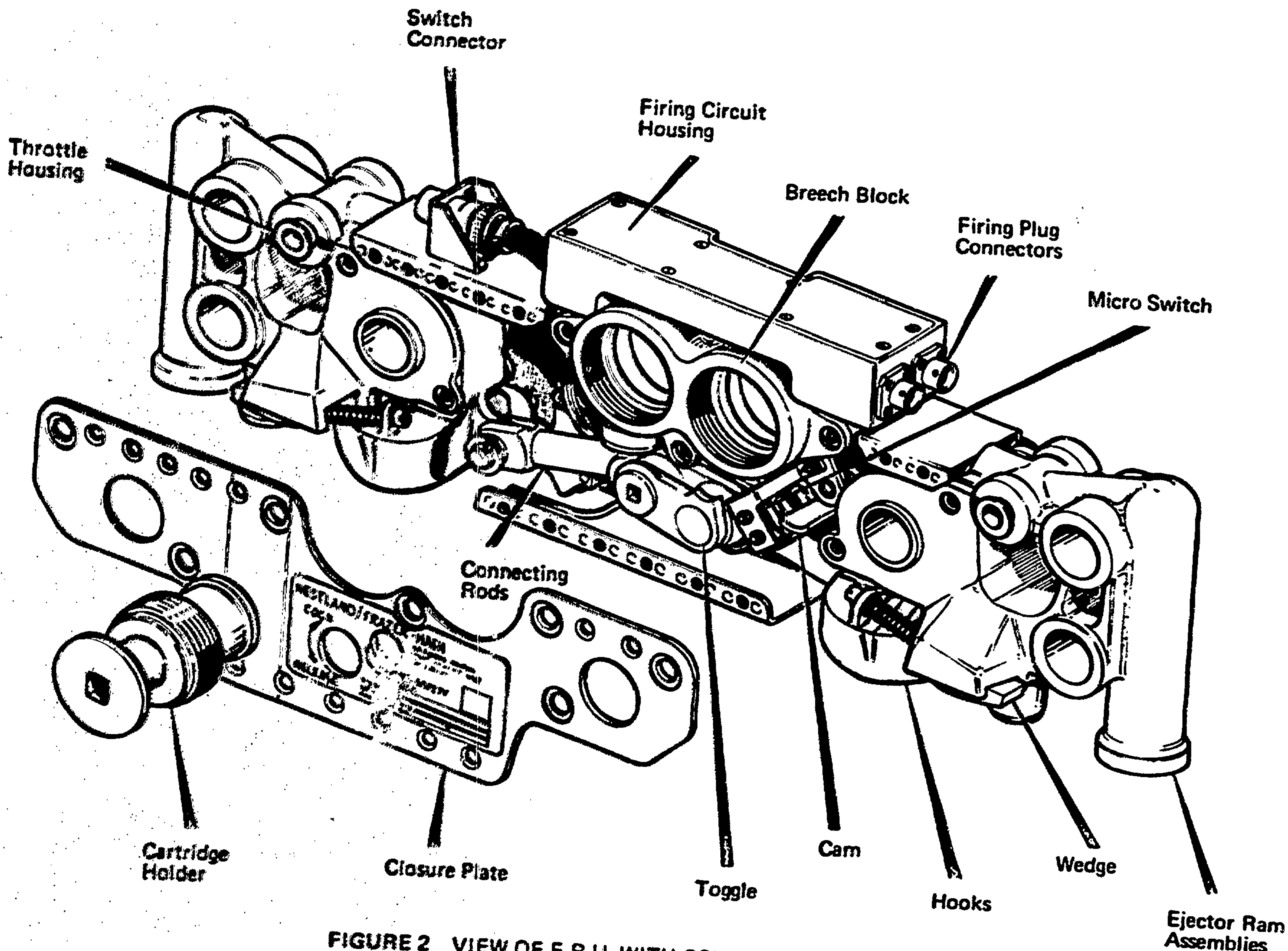

FIGURE 2 VIEW OF E.R.U. WITH COVER PLATE REMOVED

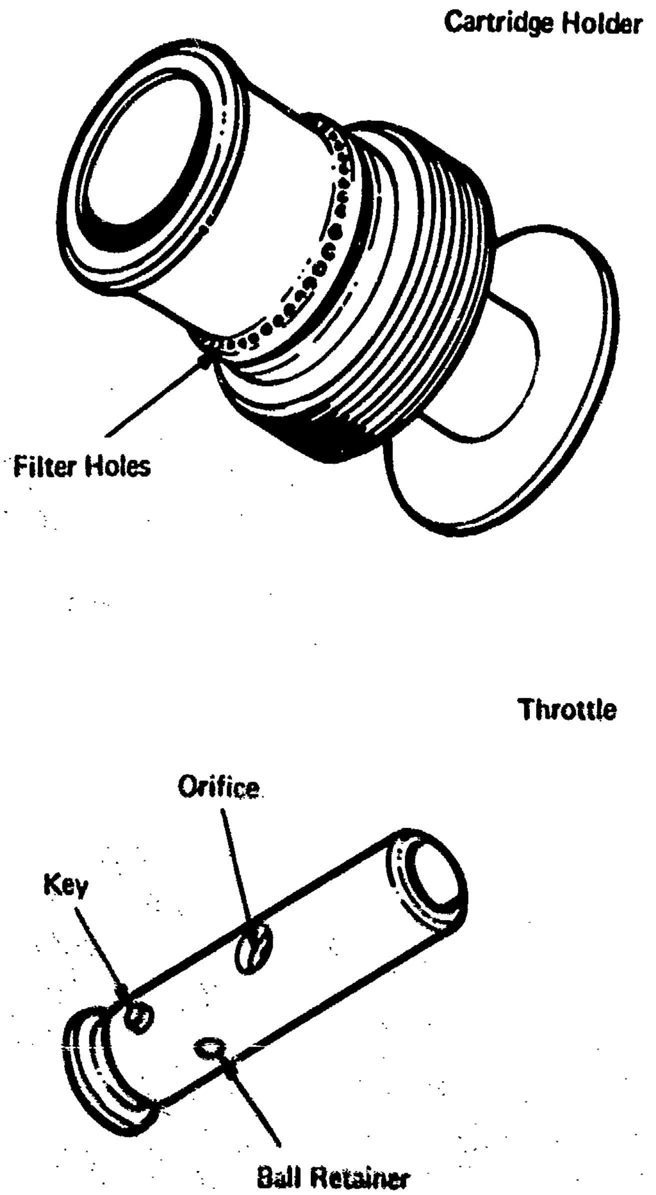

FIGURE 3 CARTRIDGE HOLDER AND THROTTLE BODY

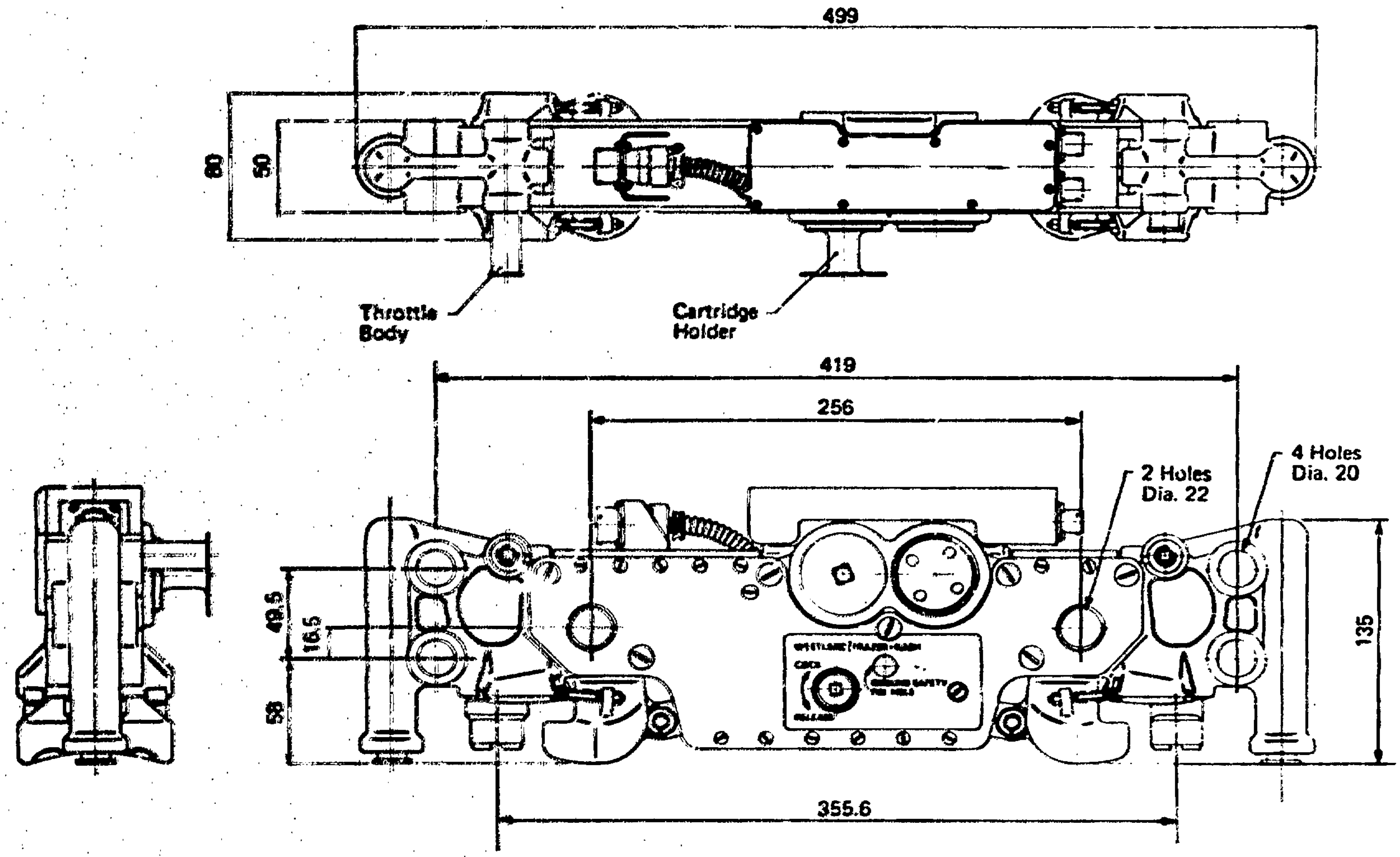

FIGURE 4 14" LIGHT DUTY E.R.U.

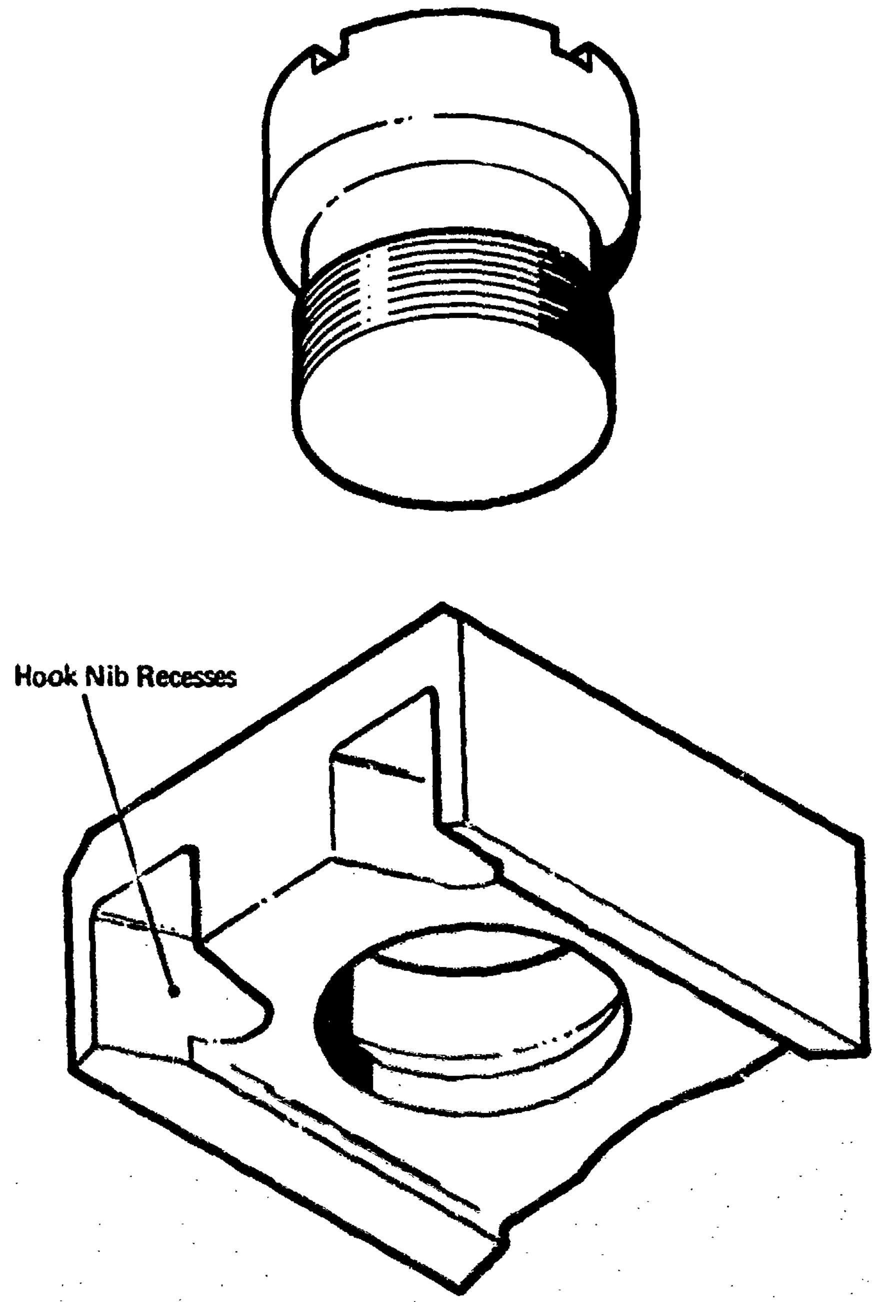

FIGURE 5 SADDLE LUG & SCREWED RING

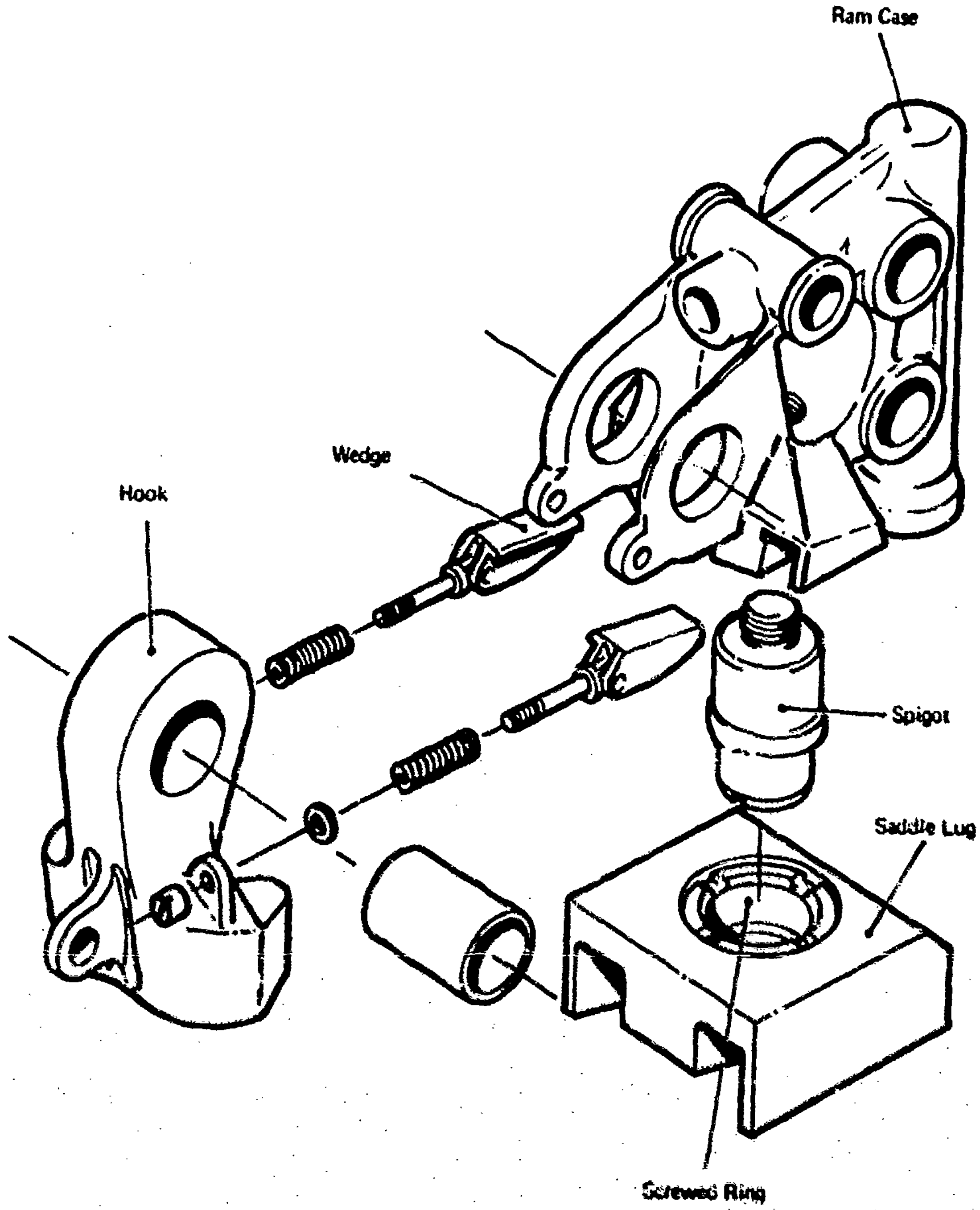

FIGURE 6 PRINCIPAL COMPONENTS OF MACE SYSTEM

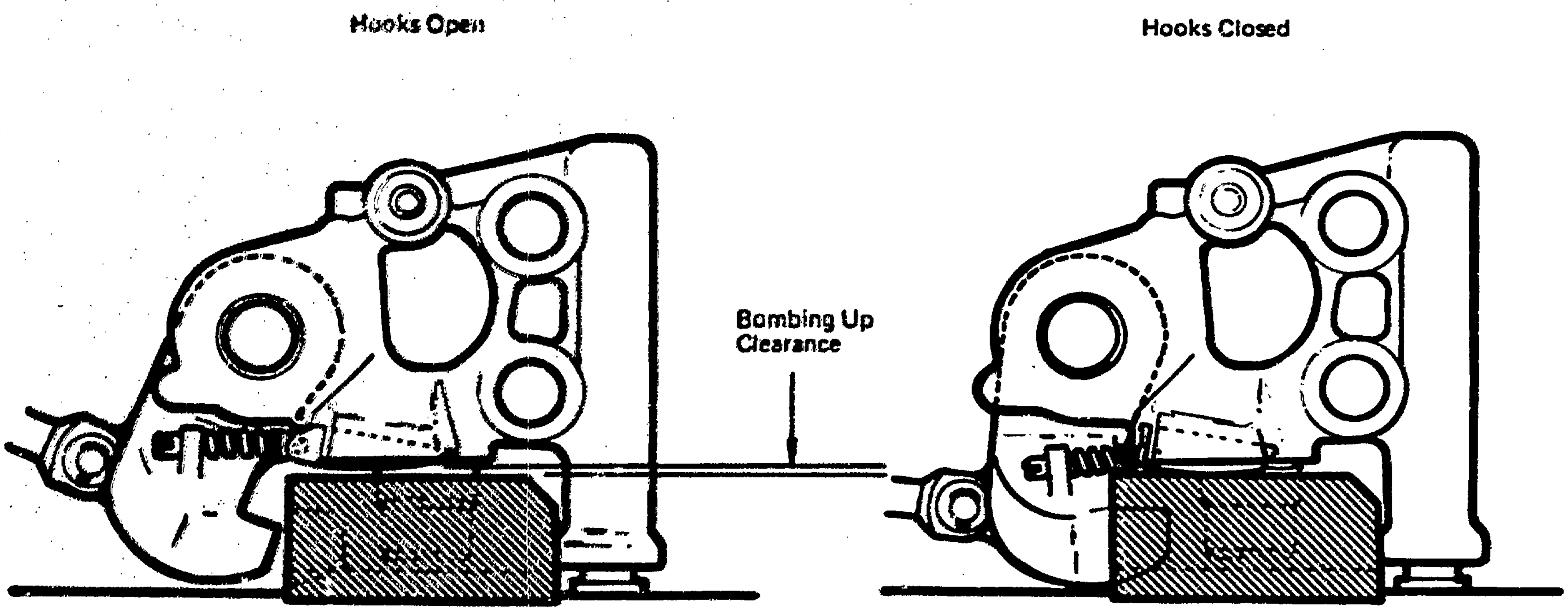

FIGURE 7   HOOKS OPEN, HOOKS CLOSED SHOWING MOVEMENT OF WEDGE

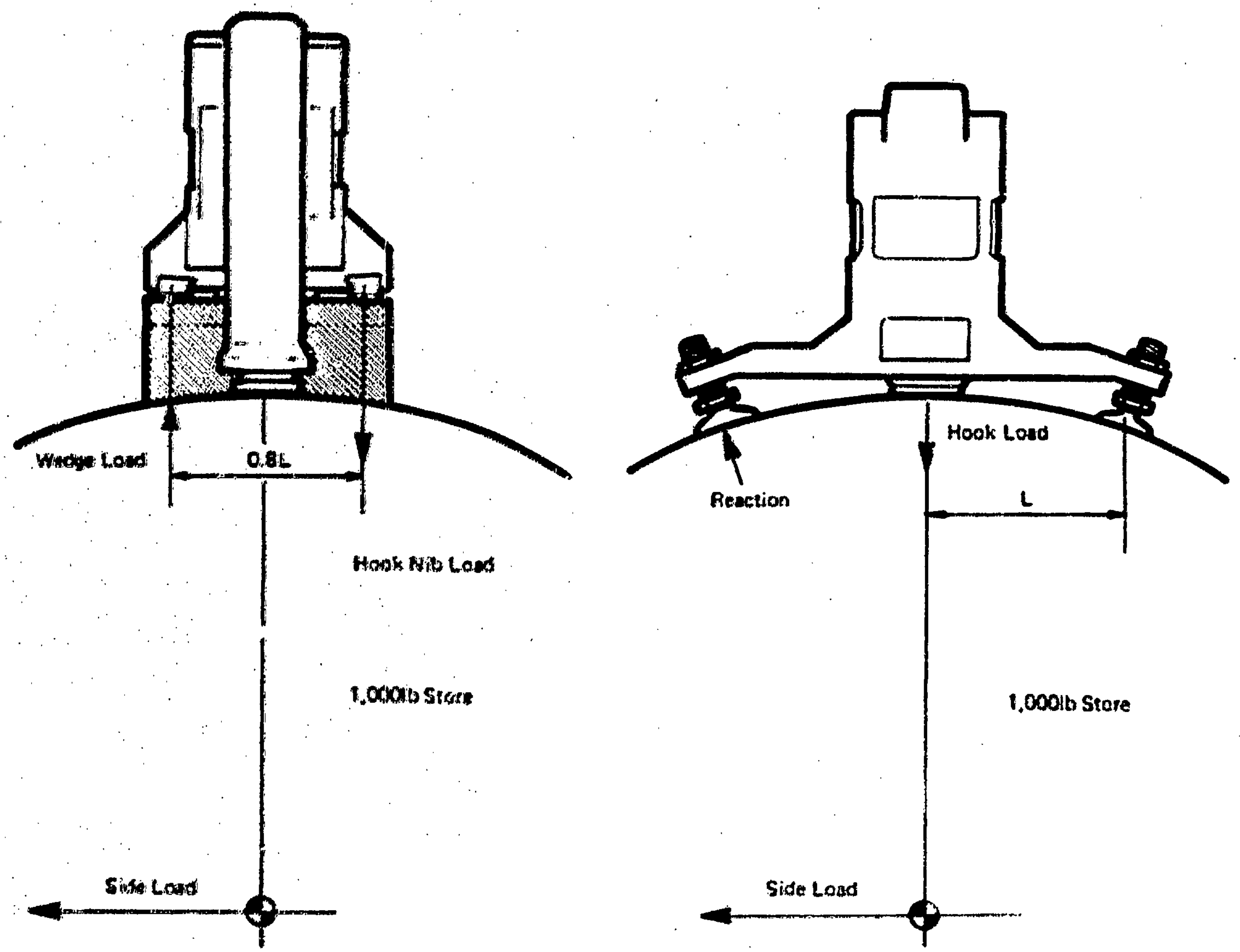

FIGURE 8 REACTION OF ROLLING MOMENTS

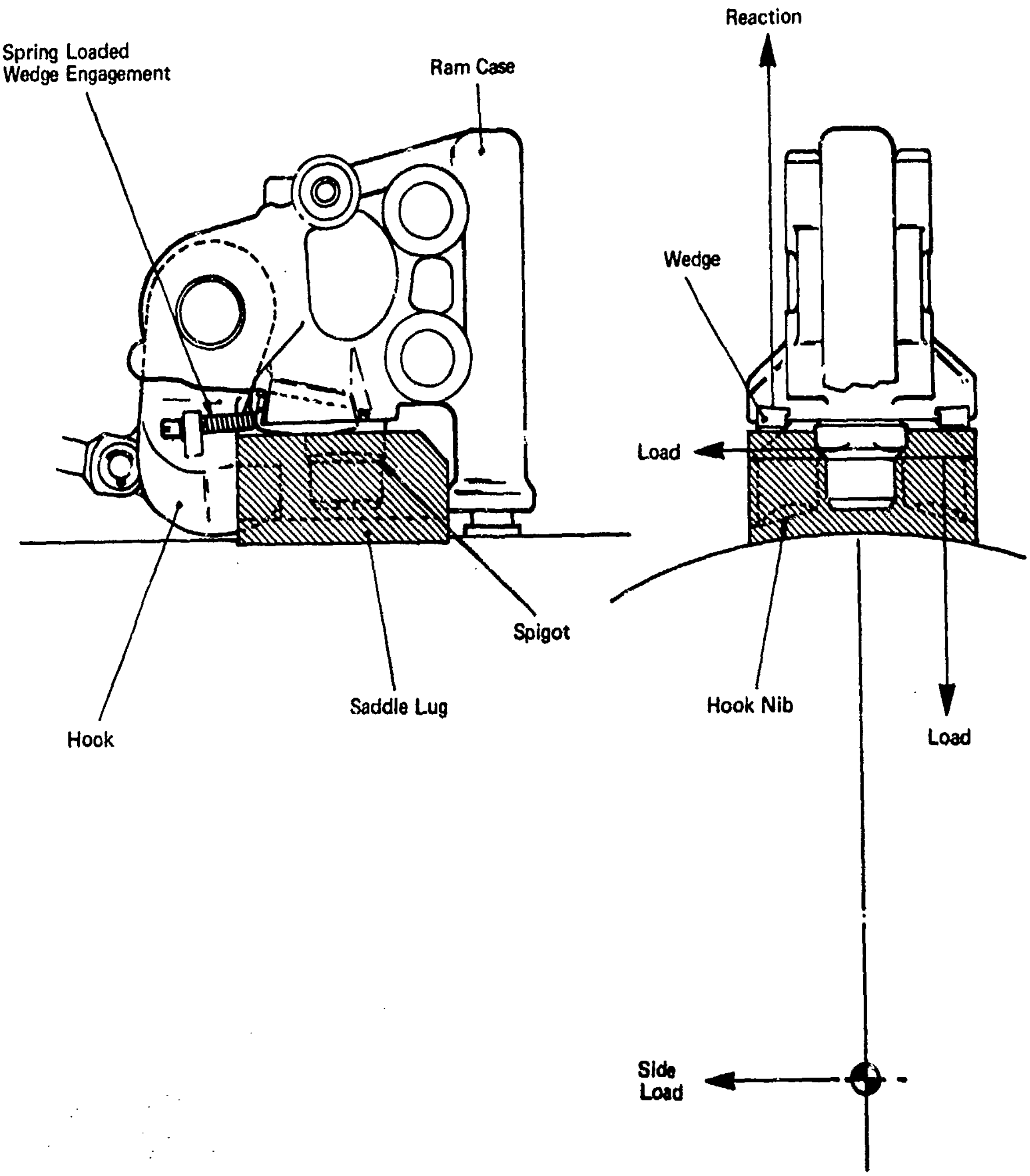

FIGURE 9 PRINCIPAL LOAD REACTION POINTS

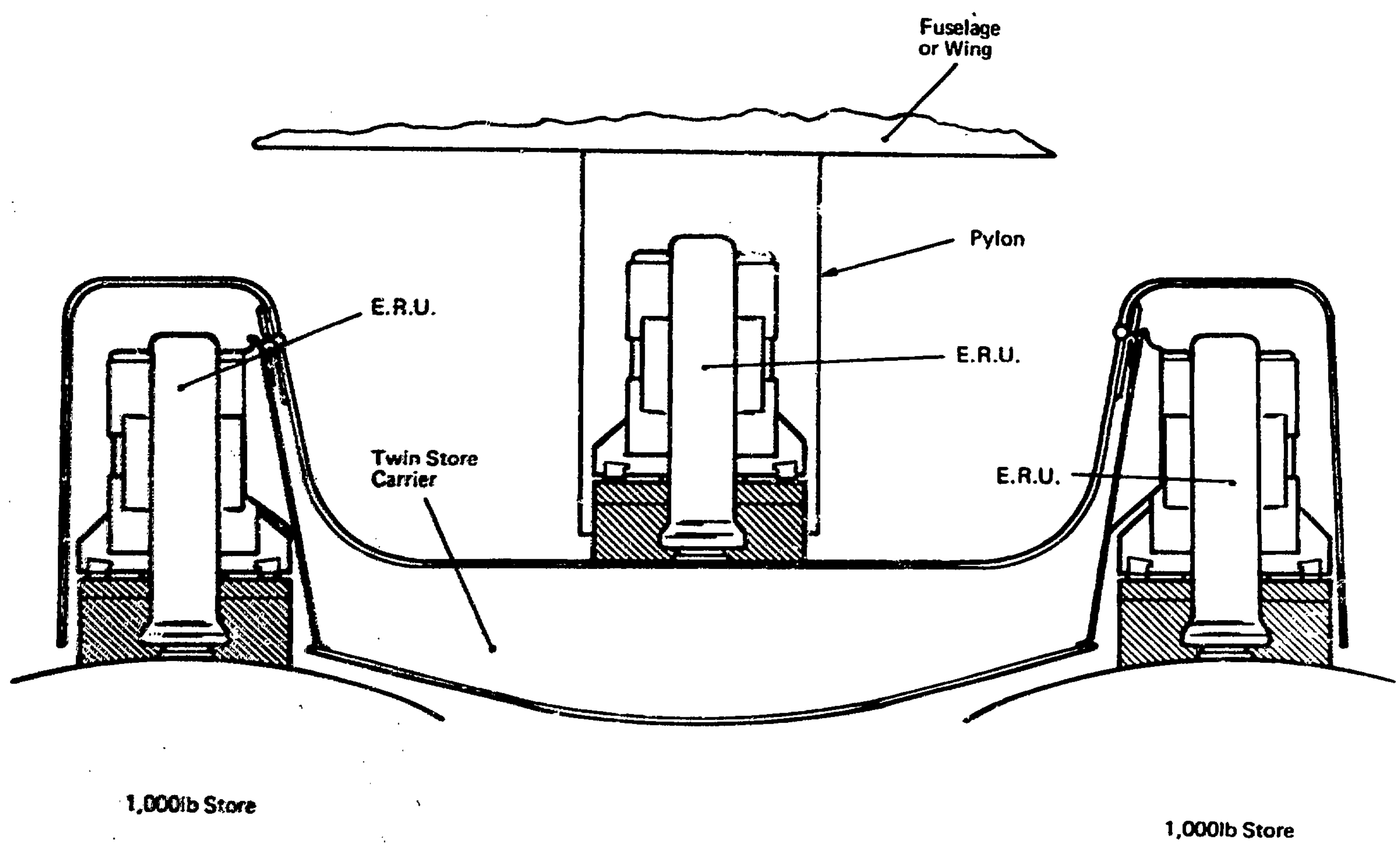

FIGURE 10 MACE UNIT SUPPORTING TWIN STORE CARRIER WITH MACE UNITS

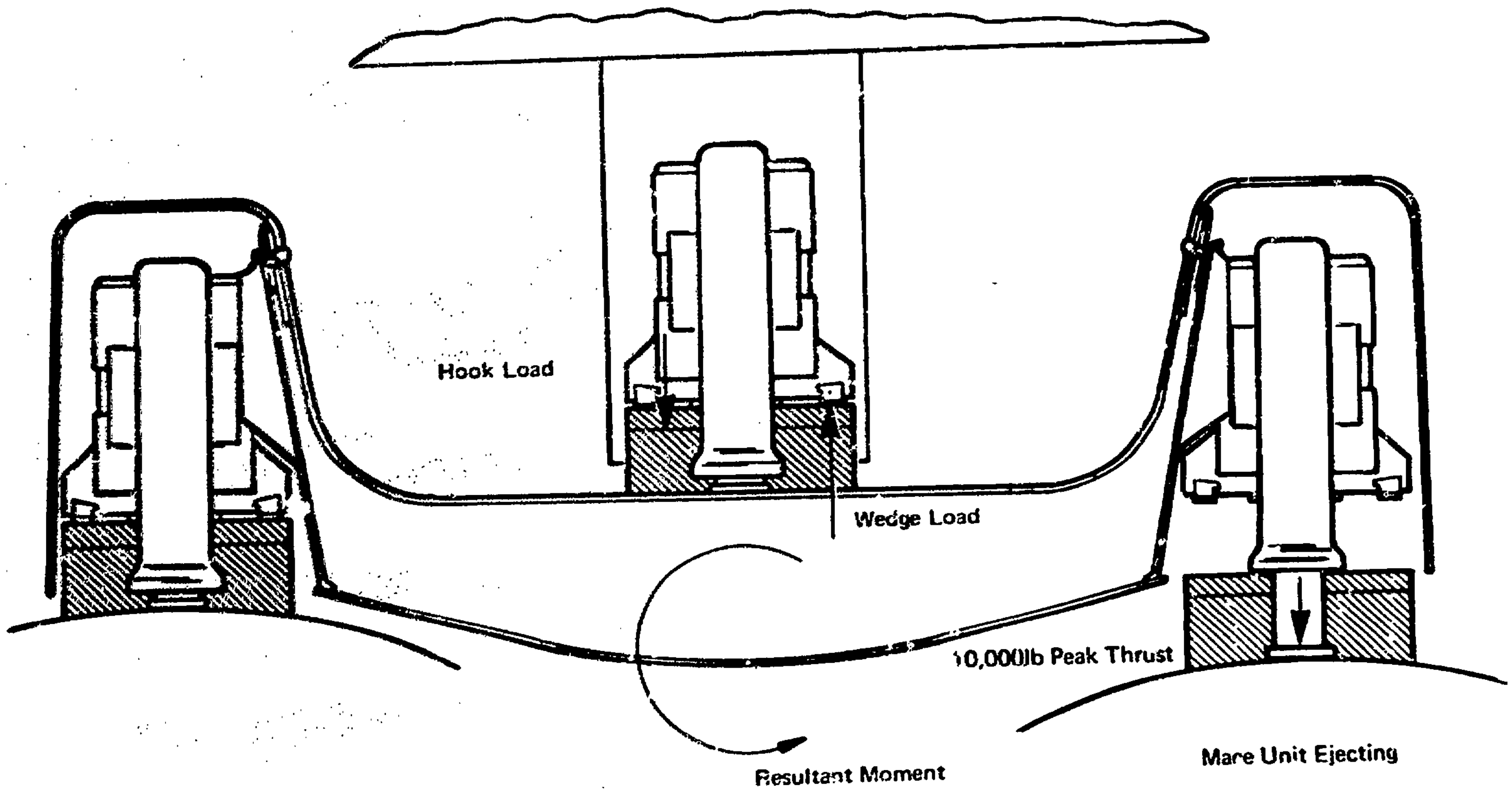

FIGURE 11 EFFECT OF EJECTION OF ONE STORE FROM TWIN STORE CARRIER

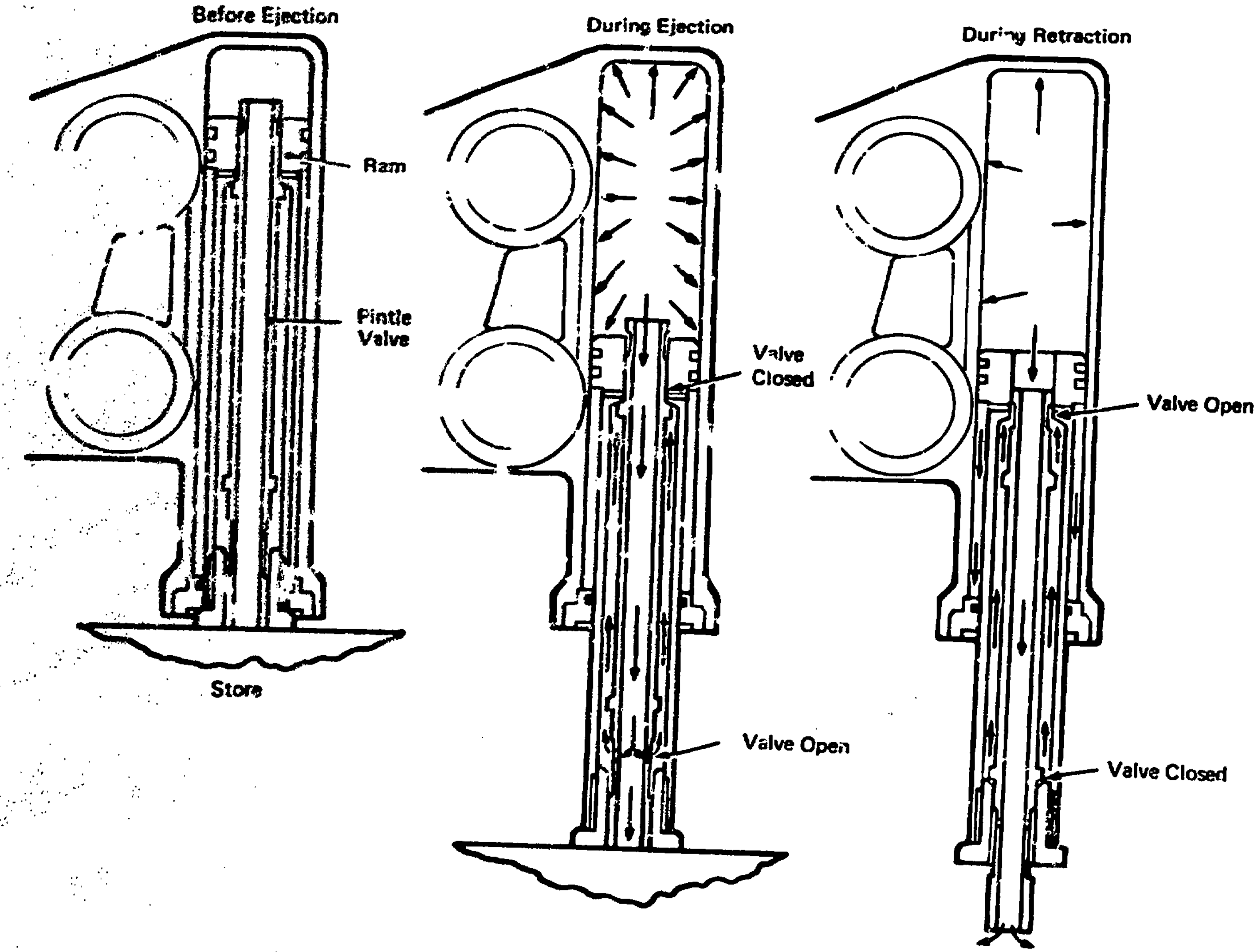

FIGURE 12 GAS OPERATED RETRACTING RAM

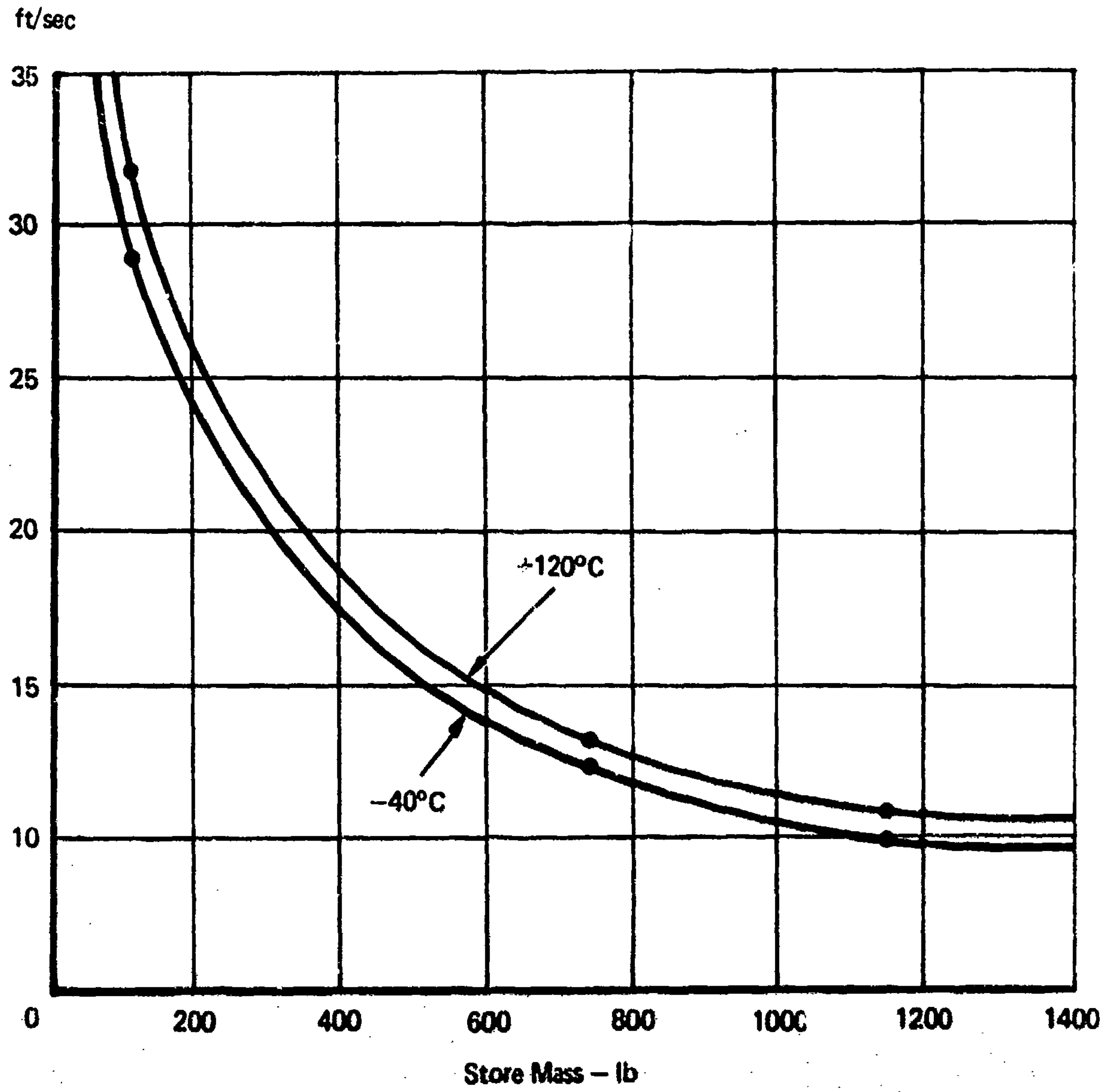

FIGURE 13 VELOCITY Vs MASS (STATIC CONDITIONS RIGID RIG)

FIGURE 14 FIRING TEST RIG

ADVANTAGES AND POSSIBLE DEVELOPMENTS
OF RELEASE AND EJECTOR UNITS USING
THE SADDLE SUSPENSION SYSTEM (U)

by

JEAN H. HASQUENOPH

R. Alkan and Company

ABSTRACT (U)

A new system for suspension and restraint of airborne stores has existed for several years. The system replaces the standard lug with a piece called a "saddle". Numerous practical applications for this system have now been developed.

We will discuss here the advantages of the system, some of the current applications, and future development possibilities for ejectors using this type of suspension.

LIST OF FIGURES

PRINCIPLE ADVANTAGES OF SADDLE SUSPENSION

Figure 1 graphically illustrates how the saddle is affixed to the store in place of the standard lug. Saddles can, of course, be used with either 14" or 30" stores.

The saddles contain:

- pockets for accepting the hook nibs
- a flat upper surface for application of the restraint mechanism (chocking wedges, screws, etc.)
- a counter-sunk hole for the attachment screw

The attachment screw contains a recess for accepting the centering pin built into the ERU and standard threads for mating with existing lug wells.

Figure 2 indicates the principle for transmission of forces between the store and the ejector.

The Z efforts, that is the pure vertical or the rolling moments Mx and the pitching moments My, are transmitted by the hook nibs and the supporting surfaces of the saddles pressing against the screw, chocking wedge, etc., forming a solid supension unit.

The lateral efforts Y and longitudinal X, either direct or resulting from the yaw momemnt Mz are transmitted by the central guide pin engaging in the saddle screw aperture.

The transmission of forces is more rational with the saddle system. Notably, the yaw moment Mz does not overload the hooks, permitting higher yaw moments to be absorbed than with the standard lug.

Precision of the store bracing is much greater than in the classic system: the unique position of the retaining surfaces of the hook nibs and the supporting surfaces correspond precisely to the reference axis of the store. The yaw position is very précise and does not depend on arbitrary screw tightening as in the classic system. This is of particular significance for special stores and for helicopters.

Reduction of aerodynamic drag occurs because the saddle presents a smaller profile and is virtually swallowed into the pylon.

There are numerous possibilities of important future developments over the classic system; some examples will be discussed later, but an immediate, positive advantage is an appreciable reduction in aircraft turn-around time due to reduced manual operations during loading.

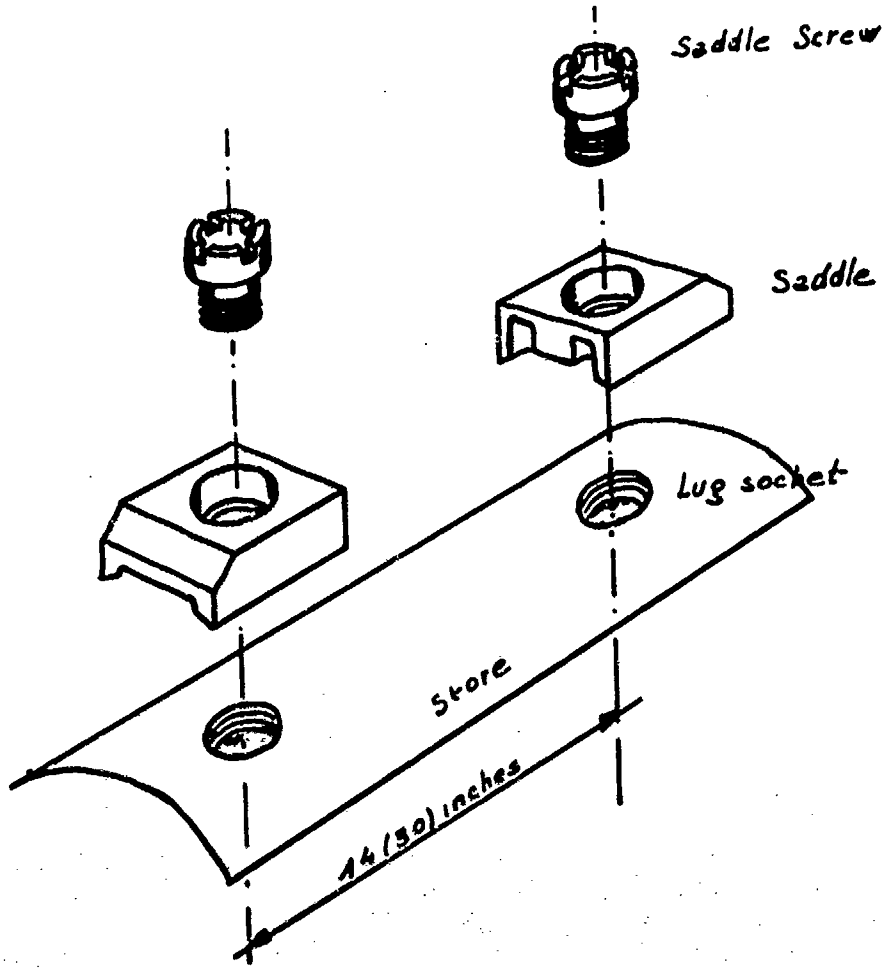

Figure 1 - Saddle Suspension Apparatus

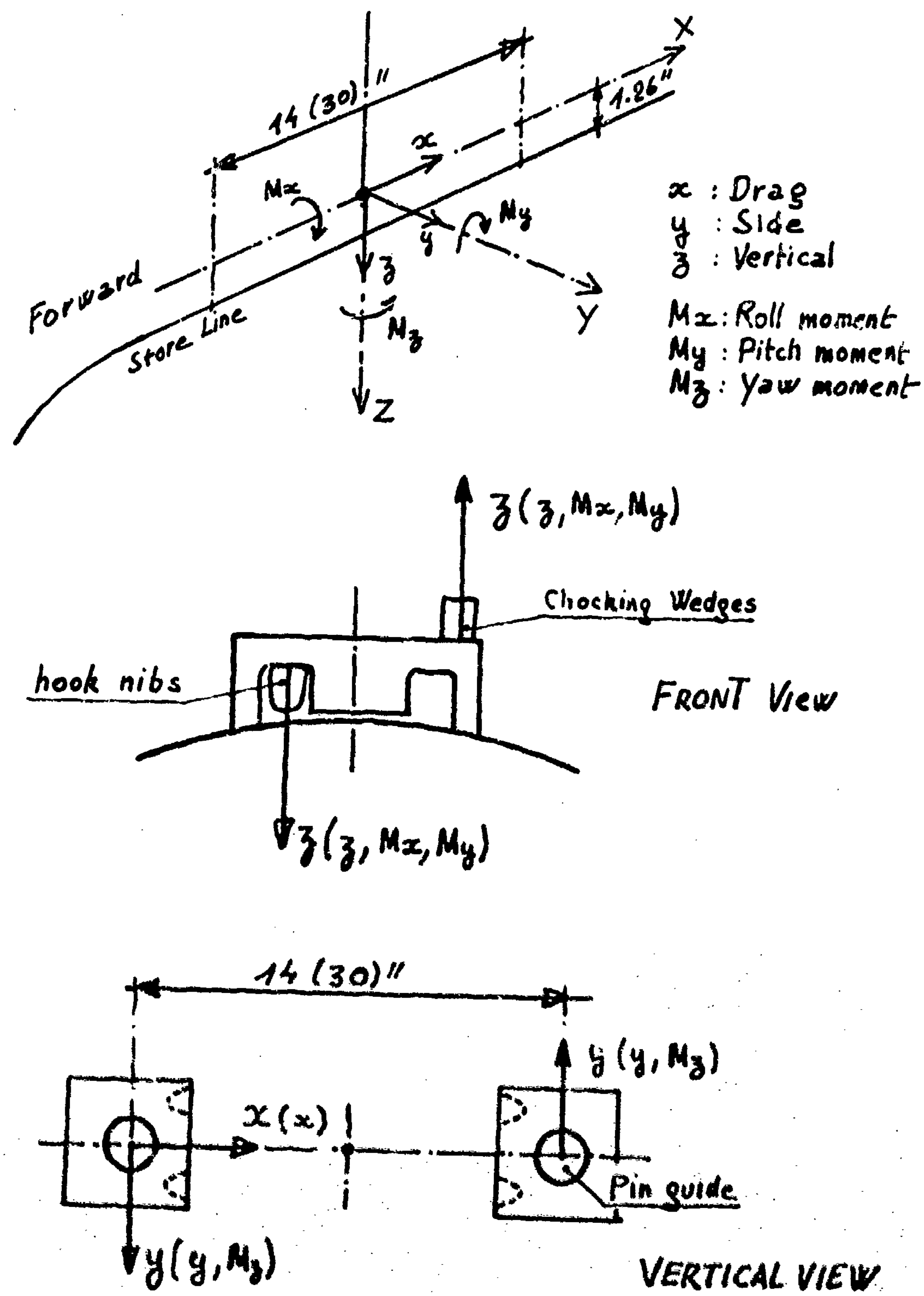

Figure 2 - Transmission of Reaction Forces

EJECTORS AND RELEASE MECHANISMS WITH AUTOMATIC CHOCKING WEDGES

Figure 3 shows a schematic and typical functioning sequences.

In this type of system the restraint of the store is obtained by the chocking wedges pressing against the upper surface of the saddle. These wedges are controlled by the hooks with the aid of a cinematic device which provides for a long travel along a shallow incline.

Each wedge is driven longitudinally by the hooks (1) through levers (2), rods (3) and double action spring devices (4).

Figure 3a shows the system with the hooks open and the wedges retracted. The store has not yet contacted the ejector.

After the store has been hoisted into position, as in figure 3b, the hooks have been manually closed - the hook nibs are engaged in the saddle pockets, but play exists between the saddle and the hook nibs (J). The wedges are still retracted because the saddle is physically holding them in this position. The spring action (4) will force them out in the next sequence.

Figure 3c shows the final sequence. The store is relaxed by the descent of the loading device - the hooks are now in contact with the saddles, eliminating the play. The wedges are positioned by the spring action to take up all slack.

The store is now restrained in Z, Mx and My by the chocking wedges and in X, Y and Mz by the centering pin guide.

An advantage of the system is that it can accept stores with surface irregularities and/or correct for deviation in screw-thread placement.

Turn-around time is considerably reduced since latching is accomplished by the simple movement of the one manual latch lever. Removing the loading device completes the loading sequence.

EJECTORS WITH CHOCKING WEDGES AND AUTOMATIC LATCHING

In this system, a logical improvement over the preceding one, a device retains the action of the wedges while the hooks are not in the latched position and a push-rod acts in a way that permits the automatic latching by the simple action of raising the store into the loaded position.

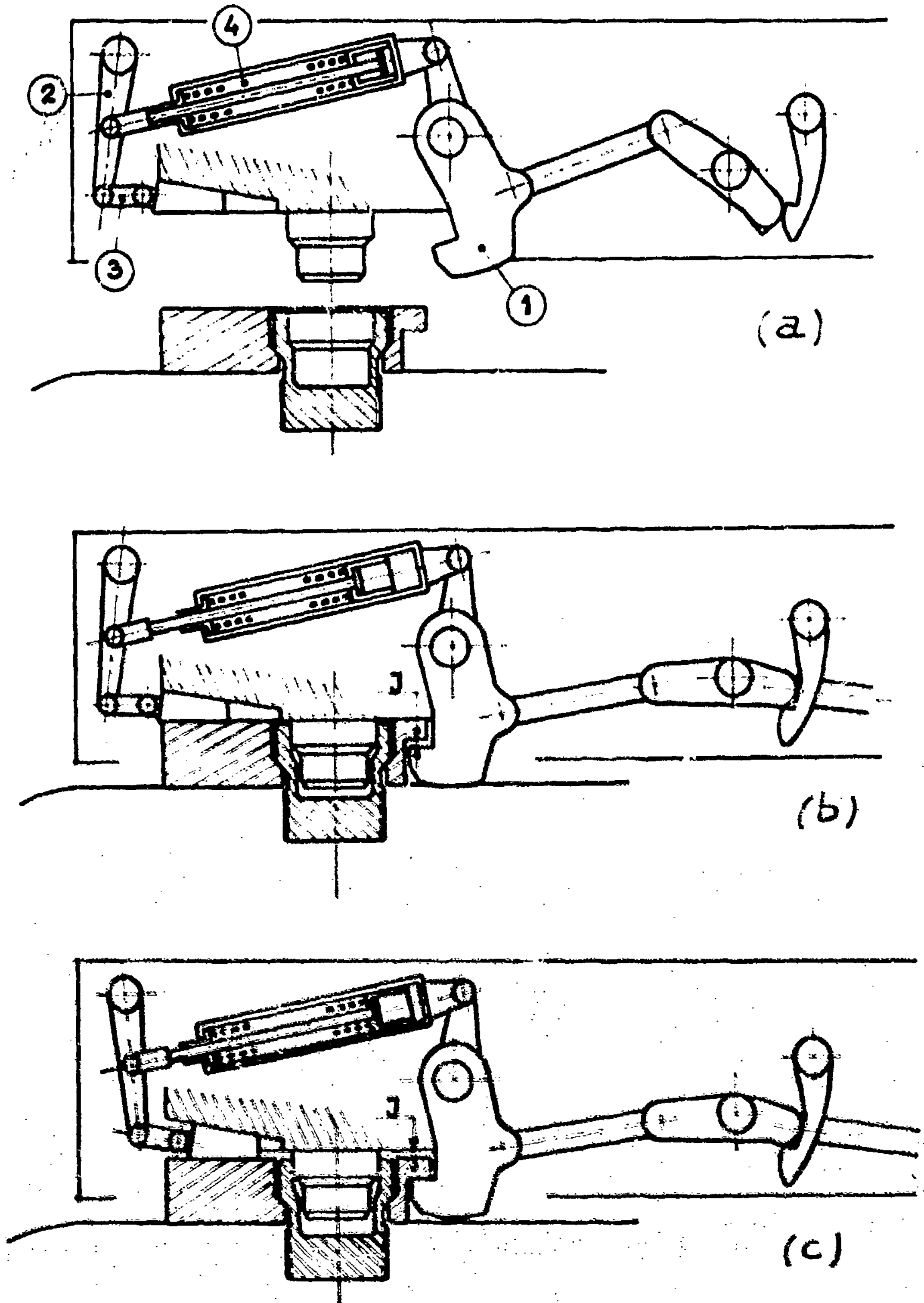

Figure 3 - Schematic of System with Long Travel Chocking Wedges

Figure 4 shows the arrangement and functioning of this unit. It comprises a return lever (5), a rod (6), an actuating lever (7) and a spring (8). In figure 4a, the hooks are open - the locking lever (9) is held in position by its hook in contact with the knee plate (10). A solid piece (11) of the latching lever retains the drive mechanism (2) through the mechanical linkage (5), (6) and (7). The small push-rod (12) is the actuator which will cause latching to occur.

Figure 4b shows the store at its maximum height. The hooks have been closed as the saddle actuated the push-rod and tripped the knee plate mechanically.

- As the knee plate tripped, it was locked in the new position by the lever (9), actuated through the movement of (5), (6) and (7).

- The swing of the lever (7) freed the drive mechanism of the chocking wedges (2), but the wedges cannot move into the lock position until the store is relaxed.

Figure 4c completes the sequence.

The advantage of this system is that it is sufficient to raise the store until contact with the lower portion of the ejector to obtain, automatically and sequentially, the latching and bracing by the wedges without any other manual action.

The turn-around time is further reduced and, in addition, this system makes possible the loading and restraint of stores on a conformal type weapons carriage.

EJECTORS WITH AUTOMATIC LATCHING AND CHOCKING WHICH INCORPORATE AN INTEGRAL HOISTING DEVICE

If the recess in the saddle attachment screw is slightly modified, it is possible to integrate a hoisting system which performs the functions of upload, latching, locking, chocking and cable decoupling - all automatically.

Figure 5 provides a schematic of such a system.

- A semi-circular slot is machined into the attachment screw recess (5)
- The ejector, fitted with a hoisting system, consists of:

  - - A winch (6) which handles two cables (7) & (8)
  - - These cables pass over two pulleys (9(& (10) and terminate in ball ferrules (11) at the center of the centering pins.

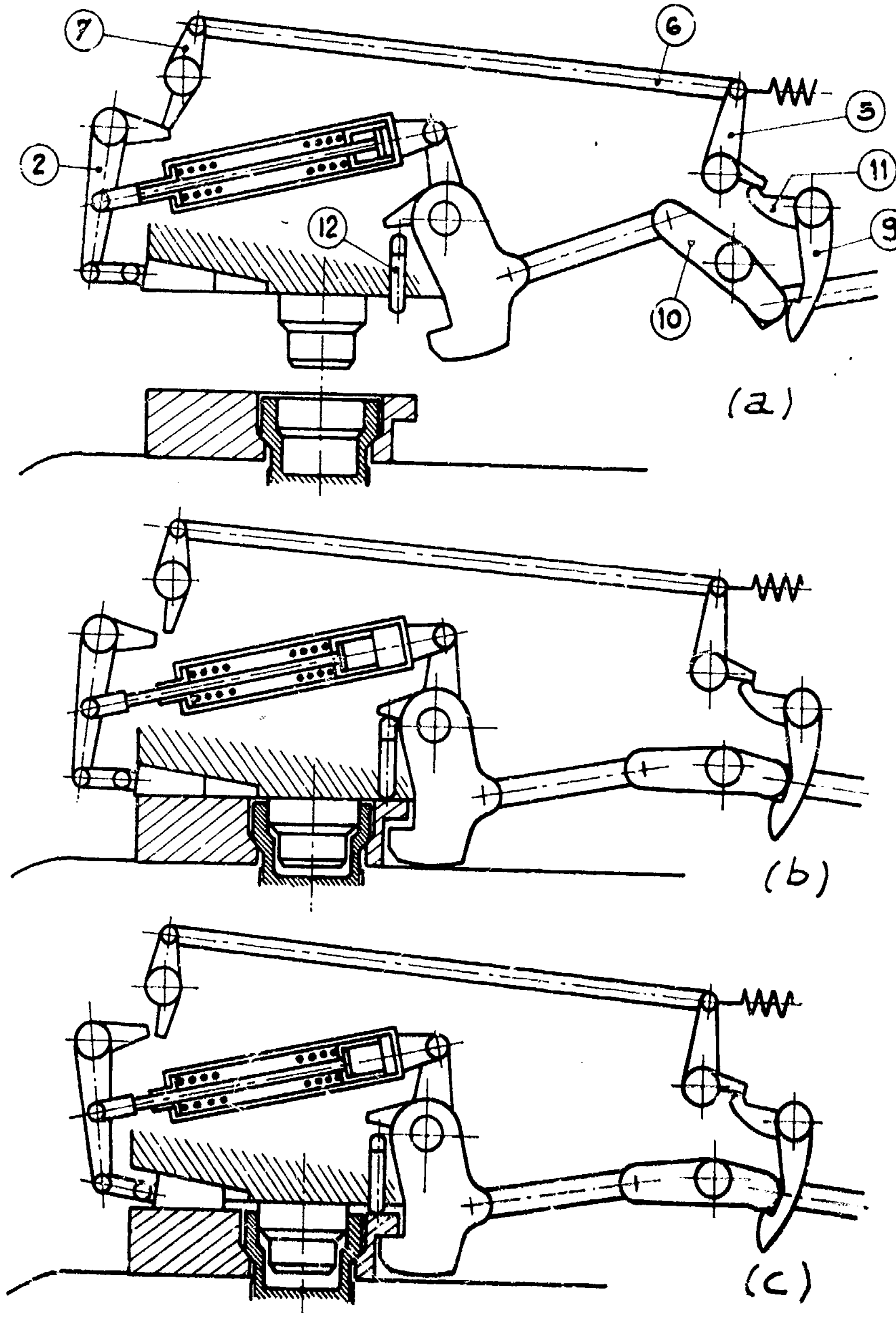

Figure 4 - Schematic of System with Chocking Wedges and Automatic Latching

- - The hooks have been modified with the addition of a small upper projection which is actuated by the push-rod (12).

The return levers (13) are connected to a linkage (14) and a rod (4). The spring (15) pushes the linkage actuating the chocking wedges. The functioning sequence is the same as in the previous example.

The cable is lowered and the cable ends are engaged in the saddle screw by inserting in place and pushing. Engagement is automatic. The store is hoisted by the winch until the saddles contact the ejector.

During and simultaneous with the final part of this action:

- the hooks are closed by the push-rods
- the knee plate is tripped and locked
- the cable ends are still engaged in the saddle screw and the upper portion of these ends contact the lever (13), causing the wedges to retract. Figure 5b shows the position at the end of the sequence.

Figure 5c represents the final sequence:

- the winch is relaxed a fraction of a turn, relaxing the store onto the hook nibs
- the spring (15) pulls the linkage (14) causing the chocking wedges to lock thru movement of (4), (2) and (3), while the cable ends are simultaneously released by the activating lever (13).

Now the store is fully loaded, latched, chocked and the cables are free of the store.

With this type of system, especially in the case of helicopter operations, it is extremely simple for one man to handle the entire loading operation. The application for helicopters in forward operating areas is obvious.

HERMETICALLY SEALED CHOCKING WEDGE SYSTEMS

A variant of the chocking wedge system permits design of ejectors or release mechanisms wherein the entire chocking and restraint device is enclosed in a hermetically sealed unit, giving total protection against any climatic environment.

This type system is shown in figure 6 and is applicable to all the ejectors already discussed.

The chocking wedge (1) is no longer in direct contact with the

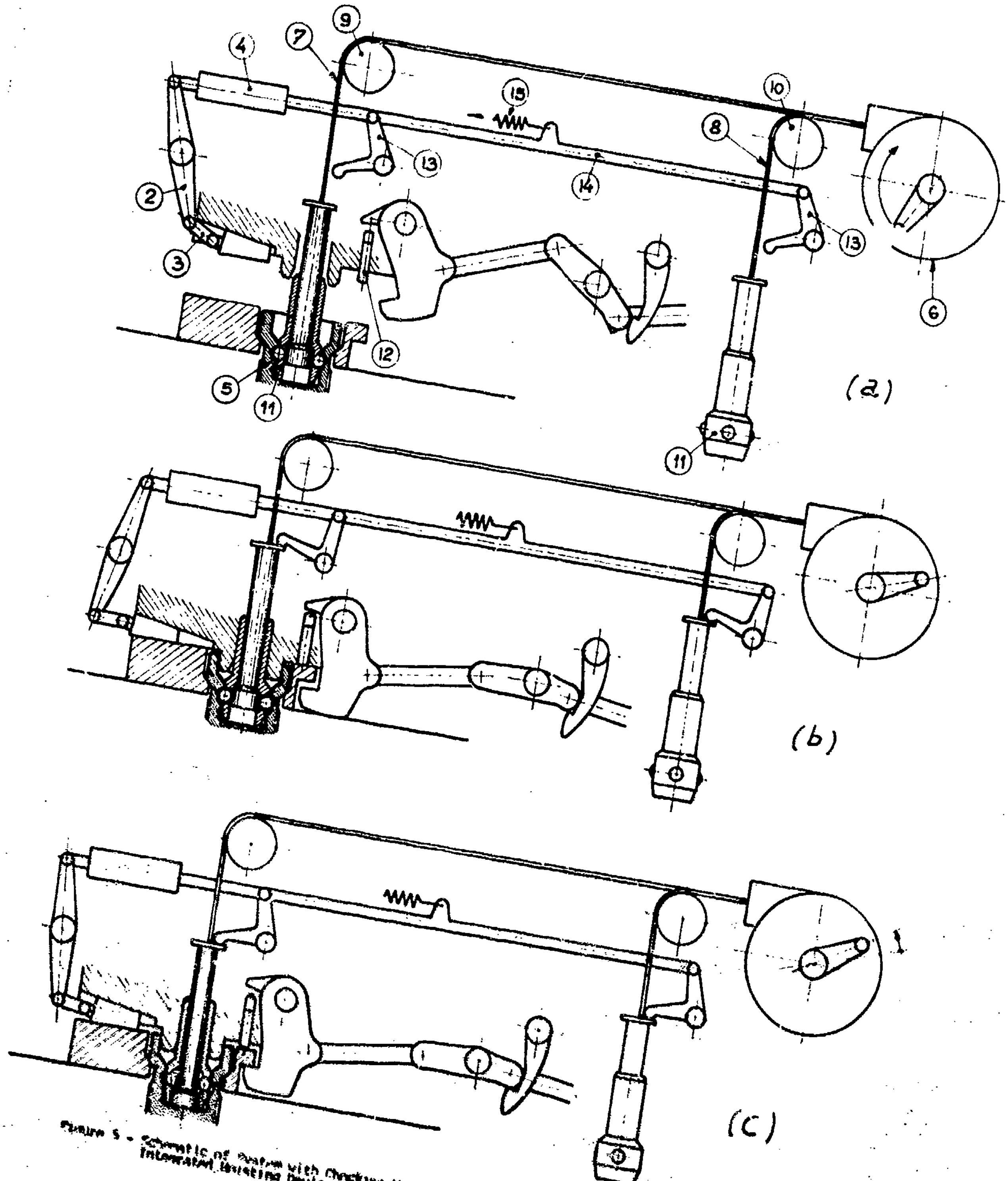

Figure 5 - Schematic of System with Checking Devices, Automatic Latching and Integrated Hoisting Device

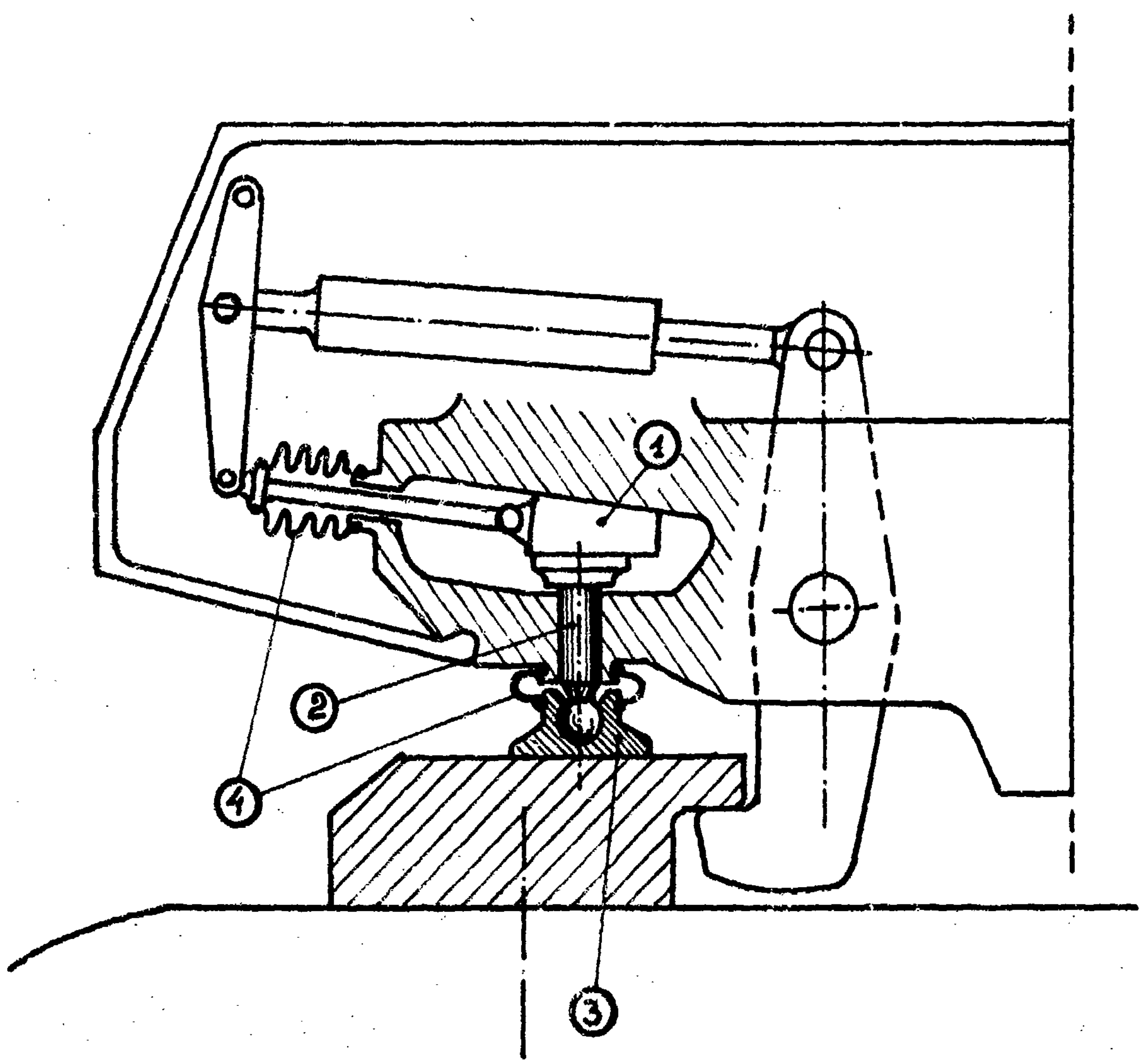

Figure 6 - Schematic of System with Sealed Chocking Wedges

saddle; it moves inside a closed housing and the transmission of reaction forces is accomplished through a vertical push-rod (2) fitted with a ball and socket foot (3). The hermetic seal (4), of any supple material, rests part on the foot and part on the ejector.

Another, indirect advantage , is the presence of the ball-and-socket foot pad, which assures better transmission of forces. The foot pad has more surface-to-surface contact with the saddle than the chocking wedge, since the lower surface of the wedge must be slightly convex to correct for store irregularities.

EJECTORS WITH REVERSIBLE HOOKS CAPABLE OF HANDLING STORES WITH EITHER SADDLES OR STANDARD LUGS

The most frequent objection to the saddle system comes from the logistician - - "What do we do with all these standard lugs already in the inventory?" The answer requires an imaginative attack on the problem - some means of providing a period of transition from lug to saddle.

Figure 7 is our solution to the problem.

The hooks are reversible, with no tools required for the change, providing an ejector which can be instantly converted from saddle to lug or vice-versa. This operation does not require the ejector to be removed from the pylon. Figure 7d shows the hook configuration.

The upper portion of the hook terminates in two notches which engage vertically at the ends of an axis attached to the ejector linkage, and this axis remains in place during the hook reversing.

To achieve the 14" spacing in both modes, the axis of the hooks has been placed at the 14" interval, assuring that spacing remains the same in either configuration. Figure 7a indicates that the chocking wedge system functions identically to that of previous saddle system configurations.

The changeover is accomplished by:

- reversing the hooks
- sliding the lateral sway brace into position

In the case illustrated in figure 7b and 7c, the sway-braces are detachable and may be snapped into position with a simply push-pull pin. (If the sway-bracing is pylon mounted, this last step is unnecessary). It is possible, though more complex, to install fold-up sway-braces,

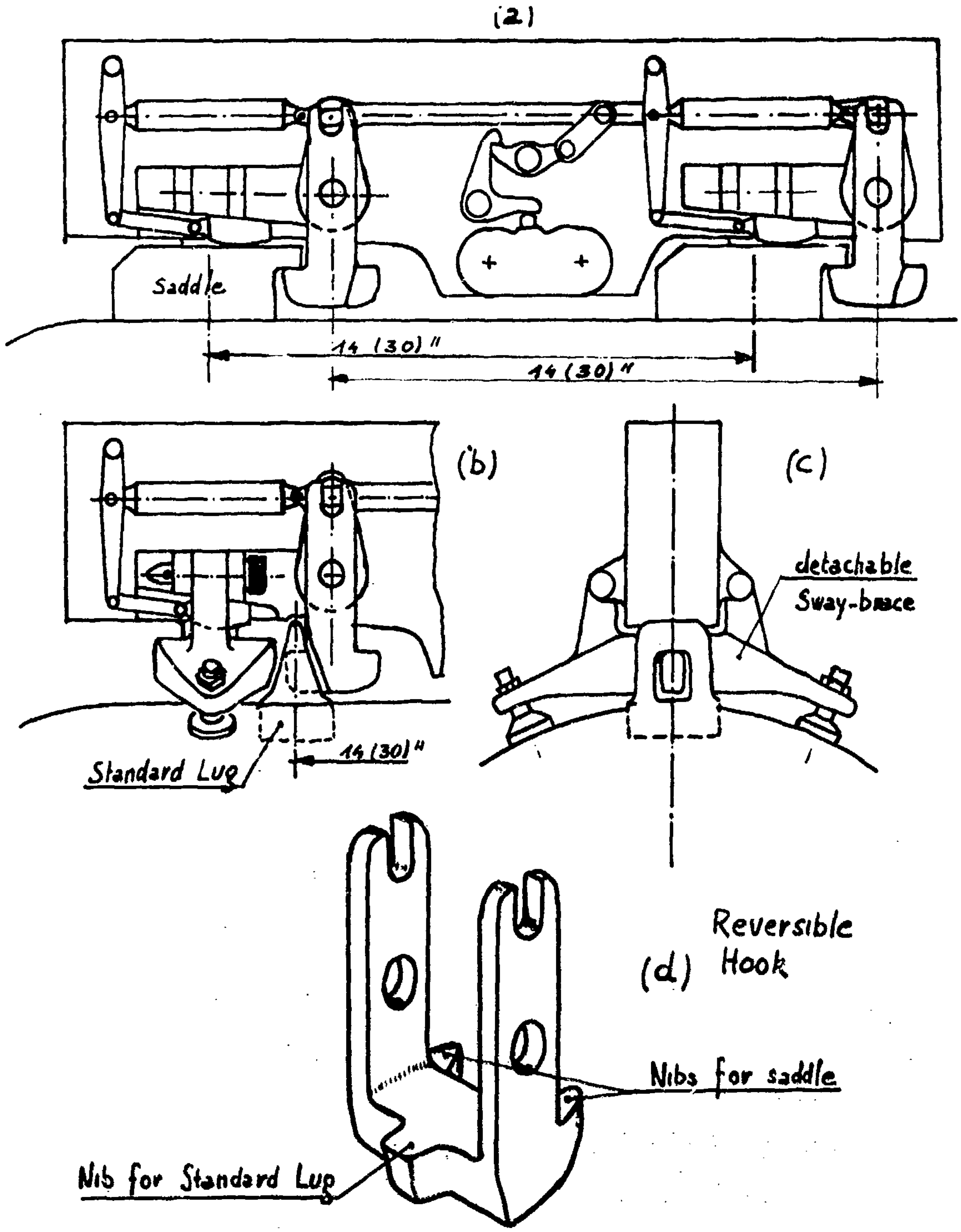

Figure 7 - Schematic of System with Reversible Hooks

which collapse into the ejector when not in use.

NOTE When changing to the standard lug, a slight longitudinal displacement in store Center of Gravity will occur relative to the CG of the saddle configuration.

CONCLUSION

This briefing has shown you various developments possible with ejectors using the saddle suspension concept - including a means of carrying stores in both the saddle and lug configuration.

For the sake of clarity, numerous mechanical details have been omitted - in particular, the auxiliary mechanisms which provide the required redundant safety features.

Let us briefly recap the advantages of the saddle system:

- precise store restraint with more rational transmission of the reaction forces involved.
- reduced turn-around time in manual load systems, and even greater gains in turn-around time with automatic latching systems.
- integral hoisting devices provide a one-man load/download capability.
- hermetically sealed mechanisms reduce environmental degradation.
- reversible hooks offer a means of transition from lug to saddle.
- precise, repeatable store alignment is possible without time consuming adjustments.
- reduction in aerodynamic drag results from the elimination of sway-bracing.

The saddle concept lends itself readily to direct integration into the store. Specialized stores such as ECM pods, fuel tanks, rocket launchers, gun pods, etc. could be improved by having the saddle built directly into the store strong-back, resulting in better storage characteristics, easier handling and reduced logistics problems. The attachment of a metallic band to the saddle, circling the circumference of the store, would permit a whole new family of lightweight pods and launchers.

The saddle opens new doors to imaginative innovation throughout the field of store suspension, release and ejection units.

AUTOBIOGRAPHY

JEAN HENRI HASQUENOPH Deputy Technical Manager of Robert Alkan and Company; Valenton, France

Mr. HASQUENOPH was born in Belfort, France on July 8, 1921. He is a graduate of the "Ecole Technique d'Aeronautique et de Constructions Automobiles (ETACA) in Paris, class of 1942. He holds a Bachelor of Science degree in Aeronatics.

EXPERIENCE:

1943/1945 Saint-Cyr Aeronautical Laboratory
Windtunnel experimentation and propeller and boundary layer experimental studies.

1945/1947 Paris Aeronautics Arsenal
Conventional engines and stato-reactors for fighter aircraft.
Centralized airborne flight control systems.
Slotted leading edge propellers.

1947/1959 Ateliers et Chantiers de France (Dunkerque)
Project engineer for the design, test and manufacture of air driven motors with pneumatic transmission by depression for electrical applications.

1959/1971 Technical and Industrial Technical Society

Chief project engineer in charge of engineering problems pertaining to the Isotopes Separation Plant of Pierrelatte.
Study, design and manufacture of special dry and tight pumps and compressors for the French Atomic Energy Commission.

1971/1975 Robert Alkan and Company

Design Office Chief Engineer and Deputy Technical Manager
Design, testing and manufacture of various combat aircraft release and ejector release units as well as a variety of other specialized aeronautical equipment.

Member, Association of Aeronautics and Astronautics, France.

ADVANCED FUZE FUNCTION CONTROL SET (AFFCS)
(U)
(Article UNCLASSIFIED)

by

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Naval Surface Weapons Center
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ABSTRACT. (U) This document describes the concept and implementation of the Advanced Fuze Function Control Set (AFFCS) developed by the Naval Surface Weapons Center, White Oak Laboratory (formerly Naval Ordnance Laboratory).

The basic shortcoming of the existing fuze function control sets (e.g., AN/AWW-4) is their inflexibility in controlling electric fuzes not depicted explicitly on the face panel of the set's cockpit control unit. The AFFCS overcomes this limitation by means of a modular design with replaceable modules in the cockpit and power supply units. All appropriate fuzing options are depicted by an LED display matrix on the front panel of the cockpit control unit. Installation of the AFFCS requires no modifications of aircraft wiring or mechanical layout.

The AFFCS gives pilots the capability of selecting all of the required fuze options in flight. It is compatible with inventory fuzes, fuzes currently in development, and provides the capacity to accommodate new fuzes without replacing the control set.

An exploratory development phase was completed FY'74 whereupon the AFFCS was successfully flight tested at the Naval Weapons Center (NWC), China Lake, California. The AFFCS concepts, technology as well as the set itself can be readily integrated into an aircraft stores management system, such as outlined in the Digital Integrated Multiplexed Armament Management System (DIMAMS) program.

INTRODUCTION

Since the inception of electrical fuzing in the 1950's, a series of Fuze Function Control Sets (FFCS) for aircraft have been developed to accommodate the various electrical fuze types. The FFCS generally comprises a high (or low) voltage power supply, a cockpit control unit (situated in the cockpit and controlled by the pilot) and interconnecting cables (see Figure 1). The fundamental limitation of the existing FFCS's (e.g., AN/AWW/4) is their inflexibility; each is committed to operate in conjunction with and control a particular family of fuzes. Due to its four high voltage signals, the present AN/AWW/4 system is incapable of controlling low input voltage solid state fuzes, or fuzes requiring more than four input signals.

The Joint Services Operational Requirements (JSOR) for fuzes require fuzes to "have sufficient arming time selections to allow safe escape of delivery aircraft in the event that the weapon detonates at the end of selected arming time." To provide this capability, the pilot (or computer) must have the capability for selecting the release condition or proper arming time for every release condition. This requires a means of communication between the aircraft and the weapon. In addition to the selection of release conditions or arming times, there is a need for the in-flight selection of fuze function modes. This capability is valuable when missions are diverted to secondary targets during flight or on patrol missions where a variety of target types may be encountered. The Naval Surface Weapons Center, White Oak Laboratory has conceived and developed the Advanced Fuze Function Control Set (AFFCS)[1] which can give Air Force and Navy pilots the capability for selecting all the required fuze options in-flight. It is compatible with inventory fuzes, fuzes currently in development, and provides the capacity to accommodate new, low or high voltage fuzes. The modular design of the AFFCS accommodates:

a. High voltage direct-wire systems,

b. Digital direct-wire systems, or

c. Remotely activated systems.

The AFFCS is configured so that it can replace the present FFCS without requiring structural or wiring changes to the aircraft.

PRESENT OPERATIONAL DIFFICULTIES

The attack and fighter aircraft of the Naval Forces are currently equipped with a variety of FFCS types. The AN/AWW-1 and AN/AWW-2 FFCS,

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[1]A. E. Pertman, et al, "Design and Fabrication of the Advanced Fuze Function Control Set (AFFCS)," NOLTR 74-84, 30 April 1974.

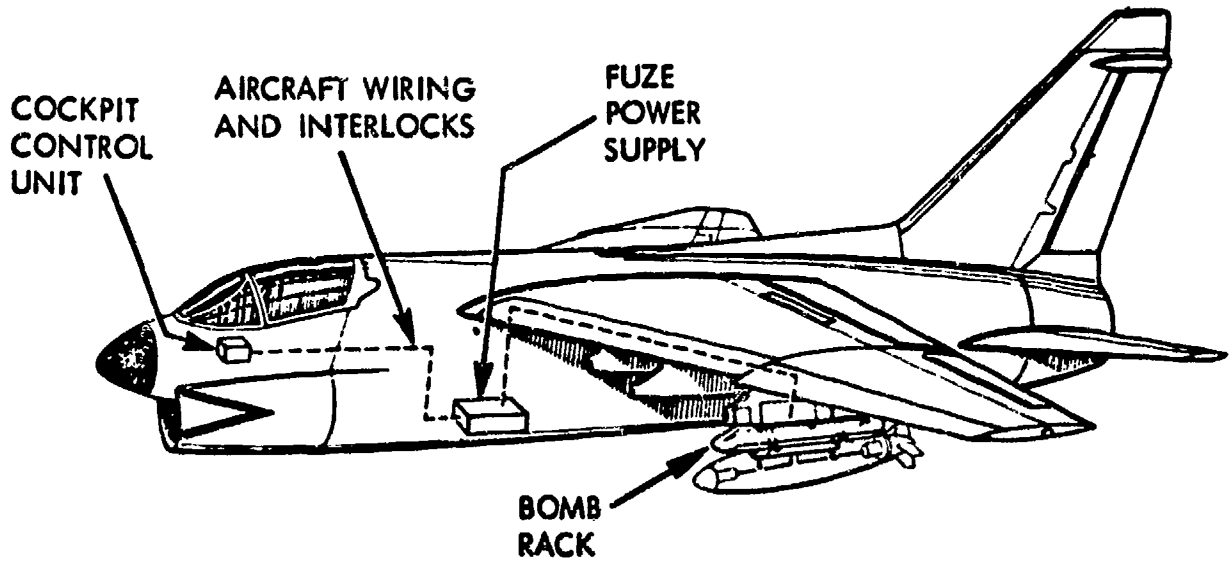


FIGURE 1 LOCATION OF AFFC SET INSIDE AN AIRCRAFT

due to their limitations, are now obsolescent. Some models have limited fuze charging capacity and all do not display the fuze options available to the pilot.

The latest FFCS is the AN/AWW-4 (Figure 2). This set is being installed in all new Naval aircraft and is planned for retrofit into inventory aircraft as funding permits. This set is completely acceptable to the current D.C. electric fuzes, Mk 344 and Mk 376. It is also compatible with the FMU-112/B fuze. However, the display panel is not acceptable for the FMU-112/B or FMU-117/B fuzes as the available fuze options are not properly depicted.

The Air Force's aircraft are currently not equipped with FFCS and must utilize the solenoid-lanyard system to obtain in-flight options. Using this system, the number of options is severely limited and the fuze options obtained by activation of the solenoid(s) are not displayed.

AFFCS CAPABILITY

The next generation of fuzes, probably for the modular weapons, should provide a choice of three arming times and four functioning modes. To accommodate these fuzes, the AFFCS provides 12 unique electrical signals. These signals and the options they can provide are shown in Table I. The polarity of the signal determines fuze arming time and the voltage level determines fuze functioning mode. Such a system, high voltage direct-link, is compatible with inventory fuzes and fuzes currently in development. In addition to providing this capability, the AFFCS is designed to provide coded digital signals that can be used in digital direct-link systems or to program a signal transmitter in a remotely activated system.

The AFFCS is also capable of being integrated into a total stores management system that utilizes digital technology. Such systems are currently in the exploratory development programs of the Air Force and Navy.

The benefits of the AFFCS are summarized below:

a. A common FFCS for Air Force and Navy aircraft can provide a basis for standardization of fuzes

b. Full operating flexibility increased by in-flight selection of available fuze options

c. Safety to delivery aircraft increased by providing a visible means of selecting and displaying proper arming times in-flight

d. Effectiveness increased by providing capability of selecting four fuze functioning modes in-flight

e. Modular design compatible or capable of being integrated with current and proposed fuze control and stores management systems

f. Compatible with supersonic carriage and release of weapons.

COCKPIT UNIT

POWER SUPPLY UNIT

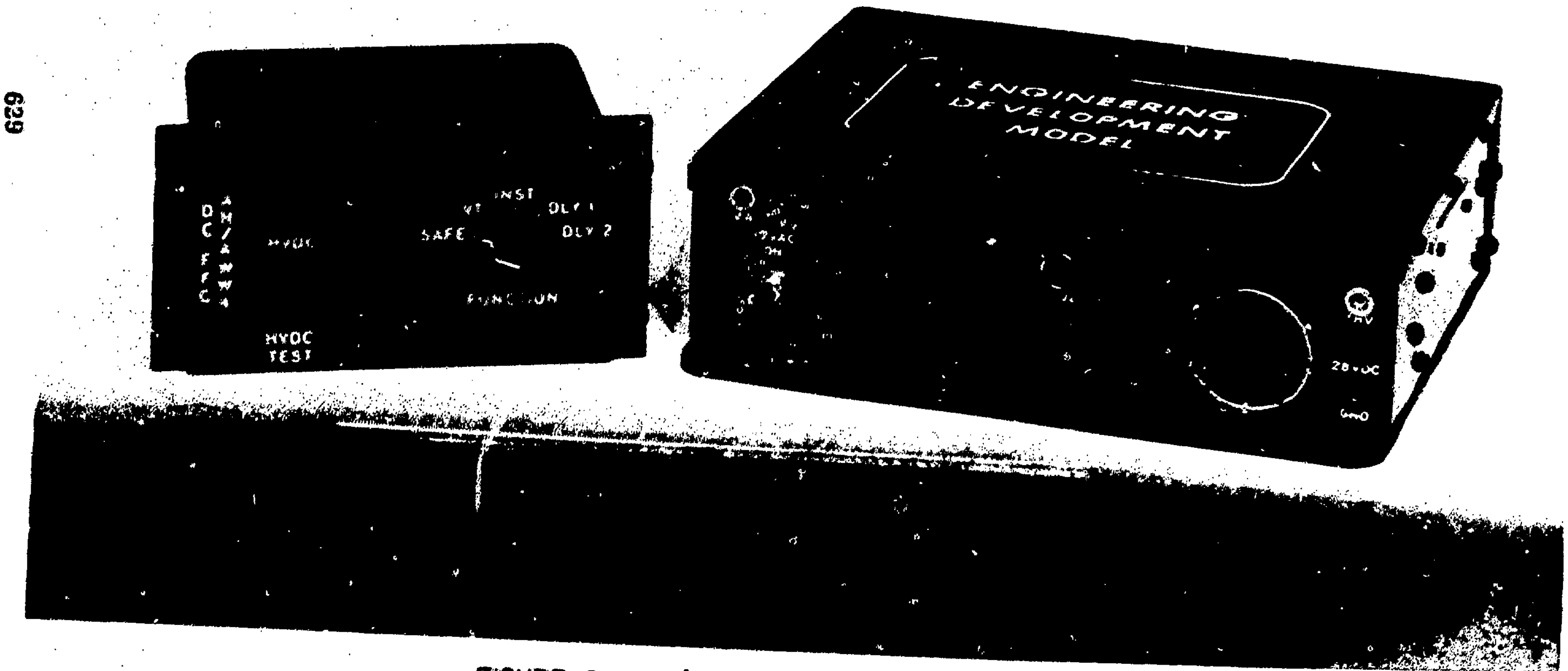


FIGURE 2 AN/AWW-4 CONTROL SET

TABLE I AFFCS HIGH VOLTAGE SIGNALS AND THEIR POSSIBLE USAGE

POLARITY	RELEASE MODE (ARMING TIME)	FUZE FUNCTION DELAYS 300V	250V	200V	150V ← DC OUTPUT VOLTAGE
+	LEVEL (10 sec)	VT	INST	D1	D2
-	DIVE (5.5 sec)	VT	INST	D1	D2
±*	HIGH DRAG (RETRD) (2.6 sec)	VT	INST	D1	D2

*Commutated signal, 1000 Hz

TECHNICAL APPROACH

The purpose of the Advanced Fuze Function Control Set (AFFCS) is to provide a system with programmable functions for updating capabilities when new weapon systems are introduced without having to replace the set itself. As depicted in Figures 3, 4 and 5 the AFFCS consists of the cockpit control unit and a modular power supply unit (also referred to as the mainframe) whose outputs are programmed responses to the cockpit control settings for a variety of air launched weapon systems, both present and planned. Also, the cockpit control unit displays are programmed by a replaceable module which can be updated as new weapon systems are added to the inventory.

COCKPIT CONTROL UNIT (CCU)

While most avionic control units consist of labeled switches to control various functions, this system's CCU has five push-button windows (Figures 4 and 5), each displaying up to five alphanumeric characters generated by light emitting diode (LED) arrays. When a window is depressed, the display changes accordingly. At any given time the CCU display depicts specific fuzes and congruent arming and functional options, thus automatically cueing the pilot through a typical programming sequence. The display functions and commensurate push-button controls are governed by a replaceable code plug module within the CCU housing.

The incorporation of the LED alphanumeric display is the reason for the versatility of the display. Each LED matrix (consisting of seven rows and five columns) has 64 possible character displays resulting in an adaptive front panel. The quantity of information needed to be displayed on the front panel by the LED's dictates the amount of supplemental circuitry required. With the advent of hybrid MSI and LSI technologies, however, all supplemental circuitry can easily be packaged within the space allocated for the present AN/AWW/4 housing.

All circuitry in the cockpit control unit, with the exception of the code plug module and LED's consists of digital complementary symmetry metal-oxide semiconductor (COS-MOS) chips and a limited number of discrete components. Utilization of COS-MOS technology provides considerable noise immunity in an electrically noisy avionic environment.

The main function of the display circuitry is to take a series of commands from the master control section so as to display the appropriate characters in the 5 x 7 LED array. A 2560-bit Read-Only-Memory (ROM) is utilized as a character generator. This ROM has a three-bit row select input, a six-bit ASCII code input (standard code for alphanumeric character generation) and five outputs. The output code will determine which diodes in the LED matrix will be energized.

To form an alphanumeric character with an addressable diode array, a scanning technique is utilized. By this method information is addressed

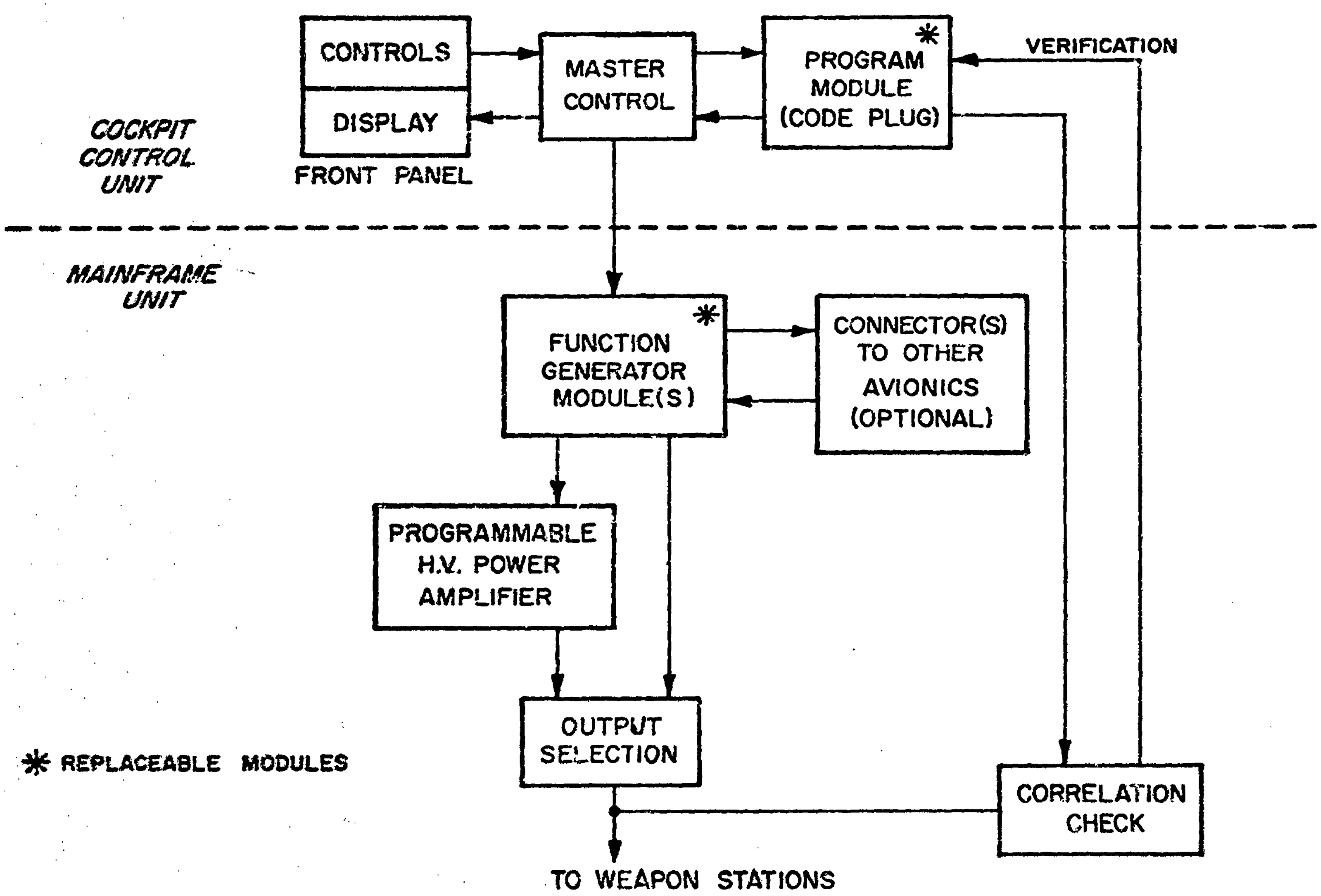


FIGURE 3 AFFCS - BLOCK DIAGRAM

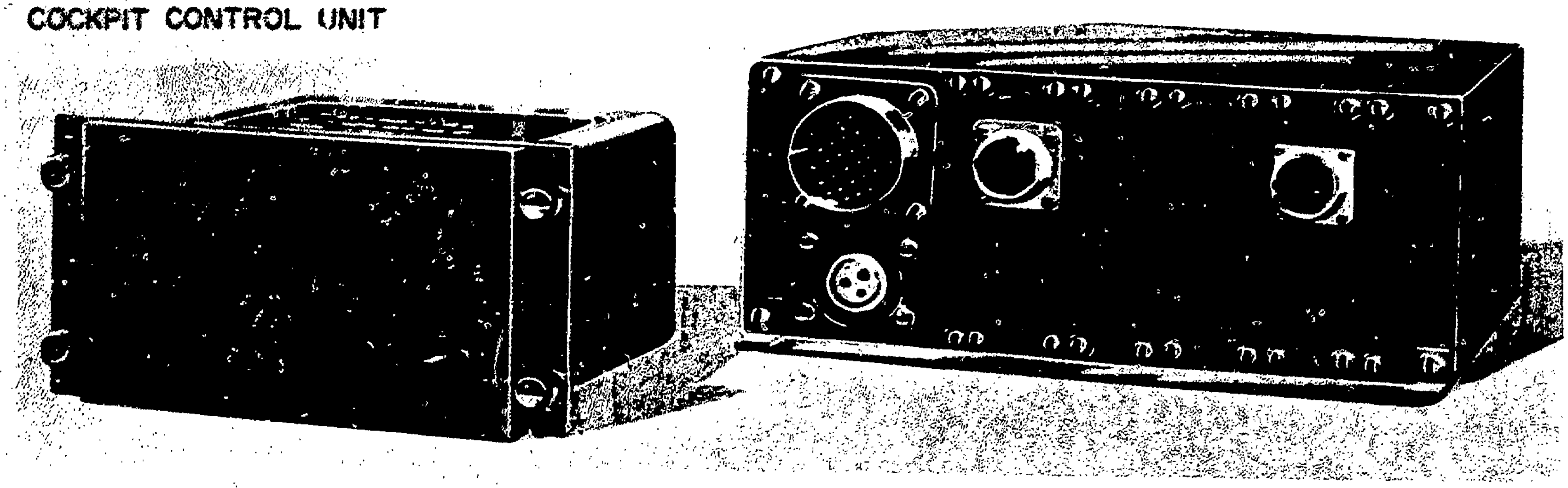
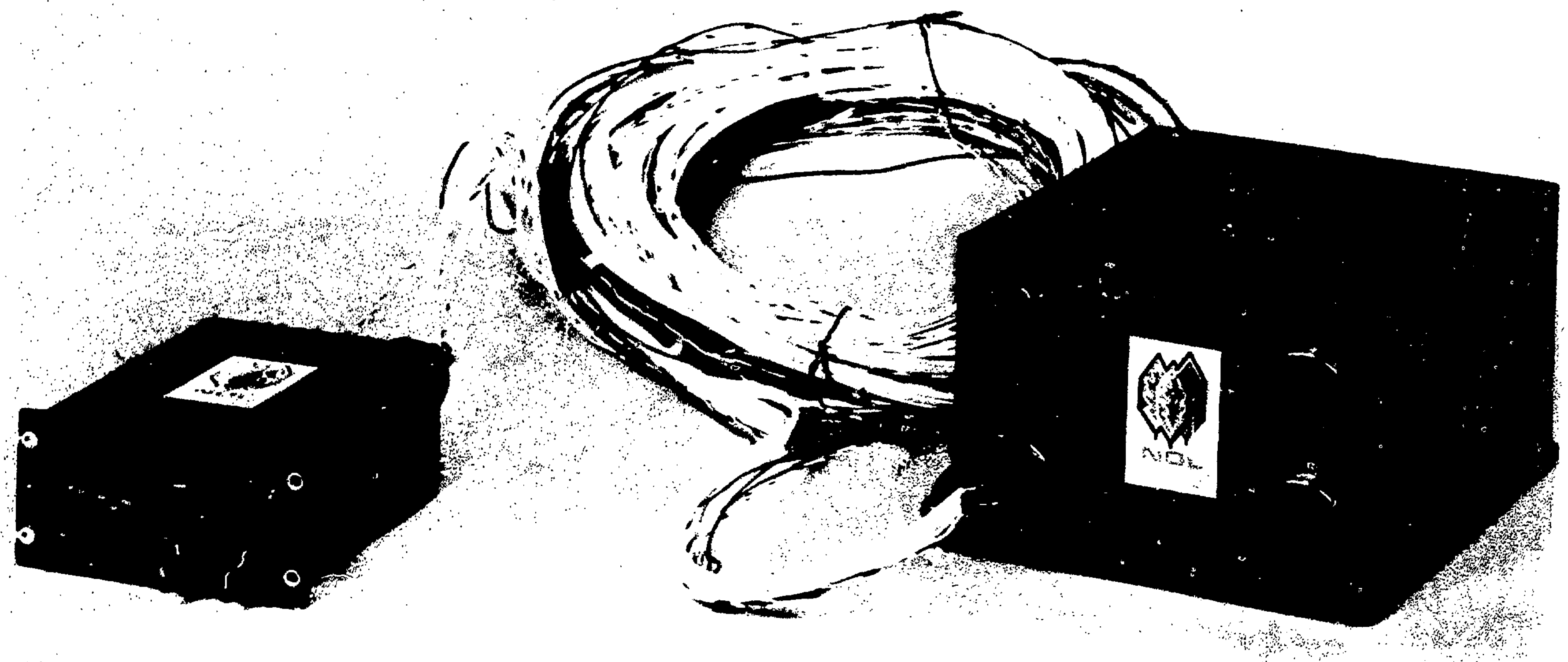


FIGURE 4 AFFCS-HARDWARE CONCEPT



COCKPIT CONTROL UNIT

MAINFRAME UNIT
(INCLUDES POWER SUPPLY)

FIGURE 5 PRESENT SYSTEM COMPONENTS

to one row of diodes at a time, energizing the appropriate diodes in the row and then proceeding to the next row. After all the rows have been selected, the process is repeated. A flicker-free character is obtained by scanning all the rows of the LED matrix at a rate of 100 times a second. Depending upon the vibration levels the cockpit panel is subjected to, faster scan rates may be necessary to eliminate possible stroboscopic effects.

The program module (also referred to as the code plug) is basically a programmable ROM. It consists of six 1024 pROMs which are interconnected with the master control section via COS-MOS logic. It is the presence of this replaceable and reprogrammable module which allows for updating the display and control capabilities of the Advanced FFCS to suit present and future air launched weapon systems without replacing the function control set itself.

MAINFRAME UNIT

The various compartments of the mainframe unit (Figure 4) illustrate the modular design of the power supply. The typical compartments (high voltage, low voltage, RASS, etc.) are communicated with and controlled by the master control (Figure 3) via the appropriate function generator module. The power supply circuit itself consists of a programmable digital to analog converter (to control the output voltage) followed by an appropriate power amplifier (to supply the necessary current). This technique for generation of power supply voltages allows for commonality of circuits between the various compartments resulting in hardware reduction and package size that is comparable to the present AN/AWW/4 power supply housing. The output selection circuitry determines whether as a consequence of a pilot-generated command (via master control and the function generator module), an analog voltage (high or low) is generated (to be sent to the bomb racks) or a digital code is presented to other avionics (such as to the X-ray generator in the Remotely Activated Stores System).

Provisions are made for system self-checking whereby the signal generated by the power supply unit is compared with the original command (programmed by the pilot) and a verification signal is presented to the pilot in form of a "READY" message on the front panel of the cockpit control box. In case of lack of verification, or if the cockpit control unit is not set to ARM, the READY message is not displayed.

Each of the compartments in the power supply unit is replaceable allowing for mechanical and electrical compatibility with any present or future air launched weapon systems.

OPERATION

Table II depicts a typical "menu" of fuze types, their respective delivery mode and function delay options. The control and display of the entire fuze "menu" presented in Table II are within the capacity of a single program module (code plug) in the cockpit control box. The AFFCS

TABLE II "MENU" OF FUZE OPTIONS PROGRAMMABLE VIA TYPICAL AFFCS CODE PLUG

FUZE	MODE (ARMING DELAY)	DELAY (FUNCTION DELAY)
MK 344	DIVE	VT/43 INST S-DLY L-DLY
MK 376	LV/RT	VT/43 INST S-DLY L-DLY
M990E	PRSET	PRSET
MK 328	DIVE	INST S-DLY
FMU94	DIVE	INST S-DLY
MK 312	DIVE	VT INST S-DLY L-DLY
AMW-H	LEVEL	VT INST S-DLY L-DLY
AMW-H	DIVE	VT INST S-DLY L-DLY
	RETRD	VT INST S-DLY L-DLY
RASS	LEVEL	VT INST S-DLY L-DLY

TABLE II "MENU" OF FUZE OPTIONS PROGRAMMABLE VIA TYPICAL AFFCS CODE PLUG (Cont'd)

FUZE	MODE (ARMING DELAY)	DELAY (FUNCTION DELAY)
RASS	DIVE	VT
		INST
		S-DLY
		L-DLY
	RETRD	VT
		INST
		S-DLY
		L-DLY

programming cycle is executed by the pilot and consists of a successive sequence of LED displays of available fuze, mode and delay options, as indicated in Figures 6 through 9.

The ON/OFF and TEST/SAFE/ARM function switches operate as follows:

a. ON/OFF must be ON for the system to be operational. When OFF, all controls and displays are turned off.

b. All programming functions (and respective displays) can be accomplished when the function switch is either in SAFE or ARM position. This switch must be in the ARM position, however, to enable the fuze activation signal at the end of a programming sequence. The spring-loaded TEST position allows a system ground test upon activation of master armament power and activation of the armament safety disable switch. Upon turning the switch to the ON position, the fuze selection is first displayed (Figure 6a). The field indicator shows that FUZE options are being displayed, while the ADD light implies that additional fuze options can be displayed by depressing the ADD push button (Figures 6a and b). To select a given fuze, the pilot depresses the window displaying the desired selection. (Note that the plastic overlay for each LED display serves as a light filter as well as a push button.) Upon selecting the AMW-R (Advanced Modular Weapon-RASS) fuze (Figure 6d), the delivery options (i.e., arming delays) which correspond to that particular fuze are next displayed as shown in Figure 7e. Accordingly, the field indicator changes from FUZE to MODE. The absence of ADD light in Figure 7e indicates that only the three delivery options displayed are possible with the AMW-R fuze.

Upon selecting the delivery mode DIVE (Figure 7f), the function DELAY options commensurate with the selected fuze and mode are next displayed (Figure 7g). As shown in Figure 7h, the pilot selects the Long-Delay (by depressing the L-DLY push button), whereupon the summary of all options selected is displayed on the front panel by the LED matrix, as illustrated in Figure 7i. This is the last step in the AFFCS programming sequence. An appropriate digital message is sent at this point by the master control section to the power supply unit in response to which a congruent voltage signal is generated by the power supply (but not sent to the bomb racks).

In order to energize the fuze, the function switch must first be switched into the ARM position (as shown in Figure 7j) and the bomb release signal sent to the power supply circuit. With the switch in ARM position, the self-checking network (correlation check, shown in Figure 3) generates the control signal which displays the READY message, as indicated in Figure 7j. Note that the absence of the READY message when the function switch is in the ARM position indicates an unsatisfactory correlation check which results in automatic disabling of the fuze activation signal. In case of such a malfunction, the RESET button can be depressed, returning the display and all controls to the initial conditions (shown in Figure 6a), whereupon a new programming sequence can commence.

FIGURE A START OF AFFCS PROGRAMMING SEQUENCE

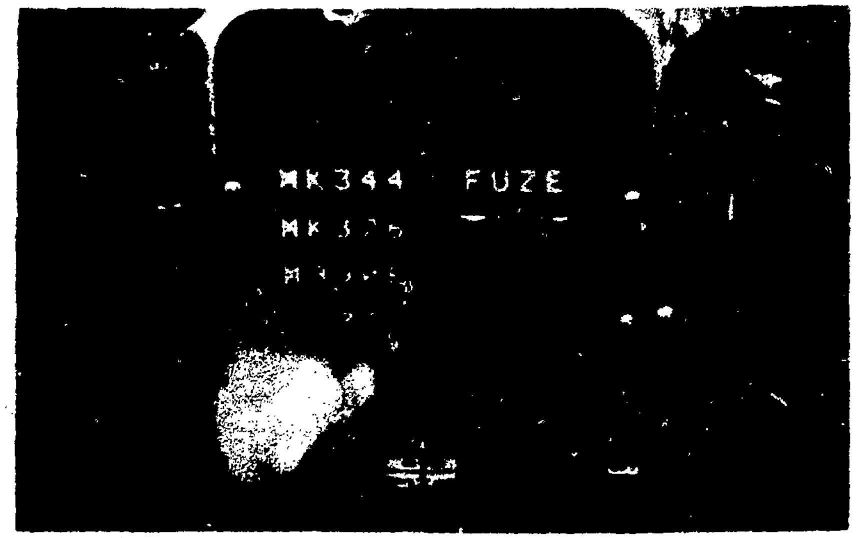


FIGURE B SEARCH FOR ADDITIONAL FUZE OPTIONS

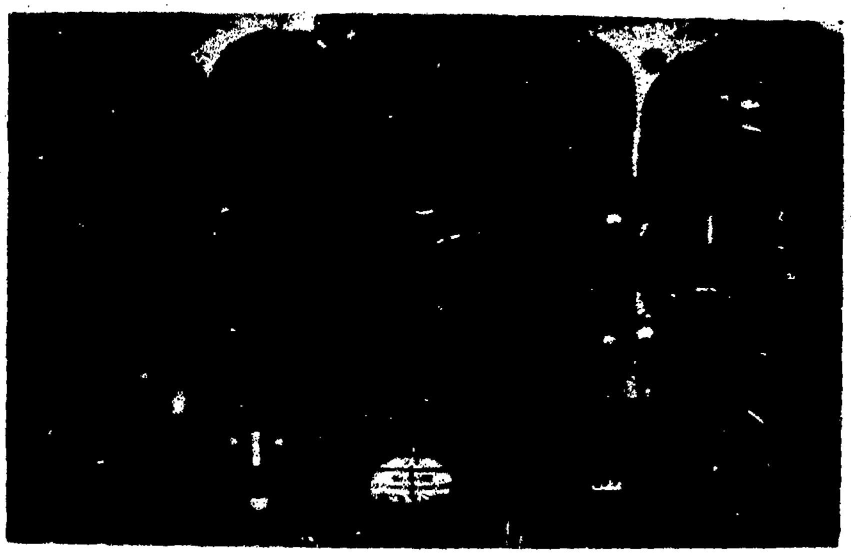


FIGURE C REMAINING FUZE OPTIONS

FIGURE D FUZE SELECTION

FIGURE 6 AFFCS PROGRAMMING SEQUENCE

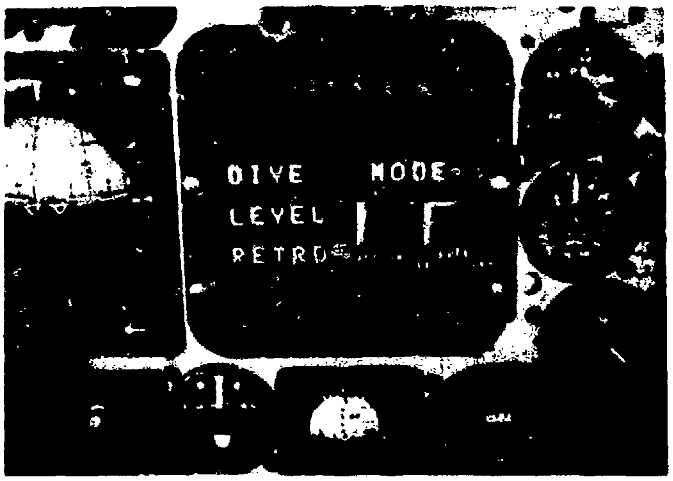


FIGURE E DELIVERY MODE OPTIONS

FIGURE F DELIVERY MODE SELECTION

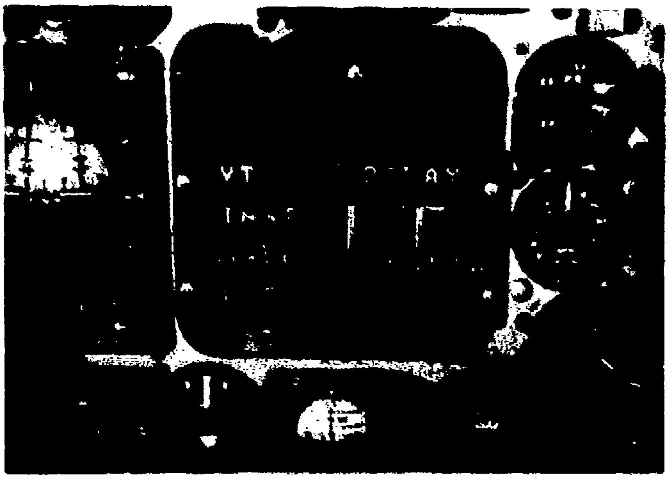


FIGURE G DELAY OPTIONS

FIGURE H DELAY SELECTION

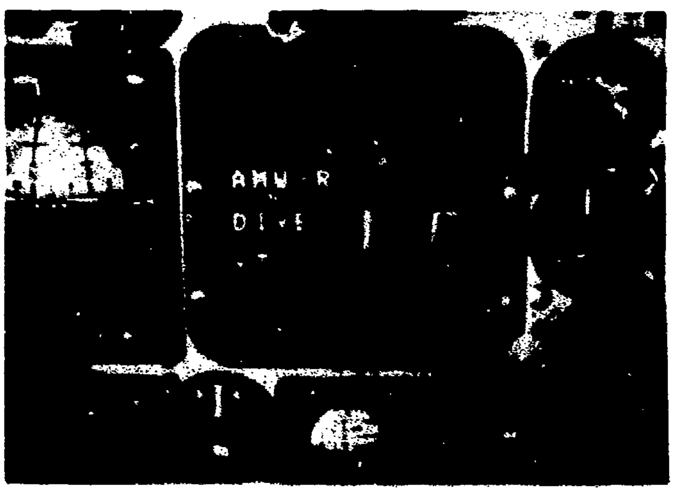


FIGURE I SUMMARY OF SELECTED OPTIONS (FUNCTION SWITCH IN "SAFE" POSITION)

FIGURE J SUMMARY OF SELECTED OPTIONS (FUNCTION SWITCH IN "ARM" POSITION)

FIGURE 7 AFFCS PROGRAMMING SEQUENCE (CONT)

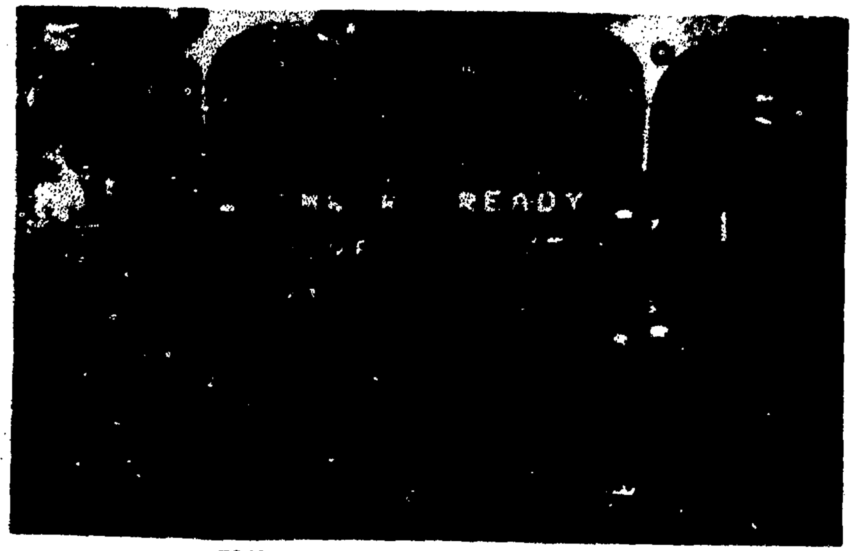


FIGURE A INITIATING A CHANGE IN THE DELAY OPTION

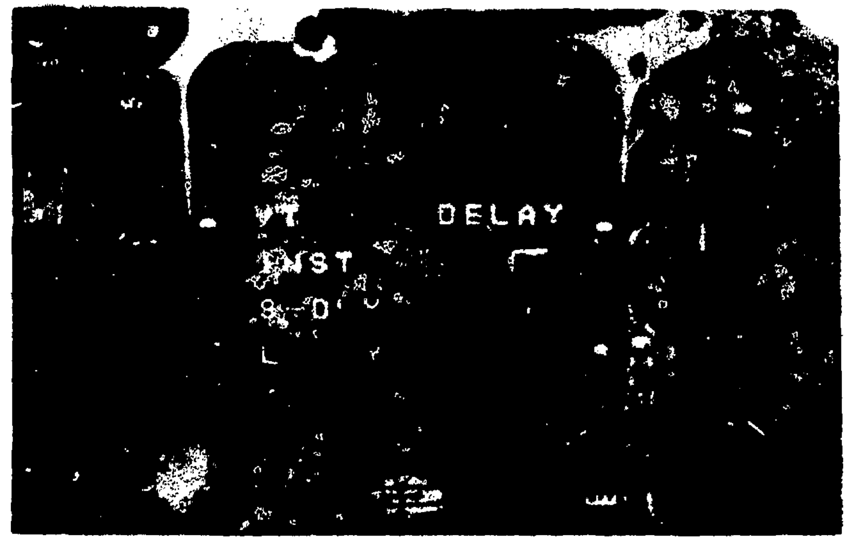


FIGURE B SELECTION OF A NEW DELAY OPTION

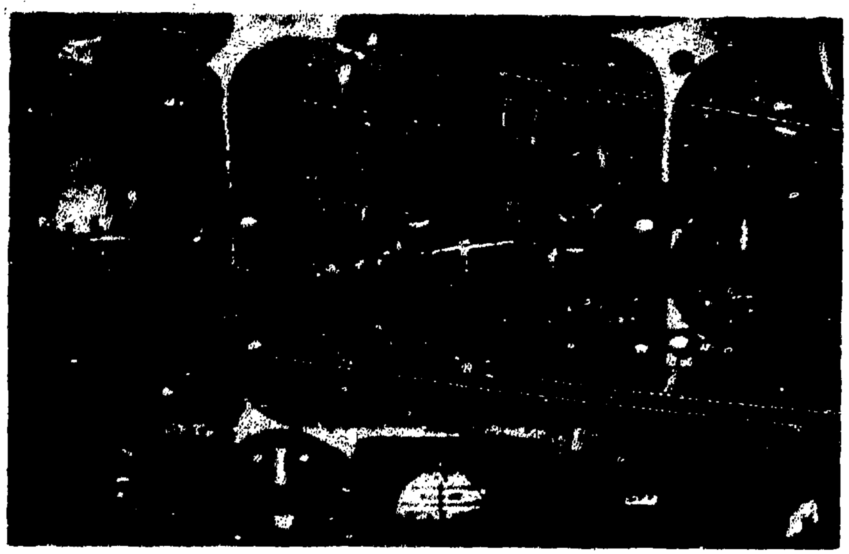


FIGURE C SUMMARY OF SELECTED OPTIONS

FIGURE D INITIATING A CHANGE IN THE DELIVERY MODE OPTION

FIGURE 8 PROGRAM CHANGE CYCLE

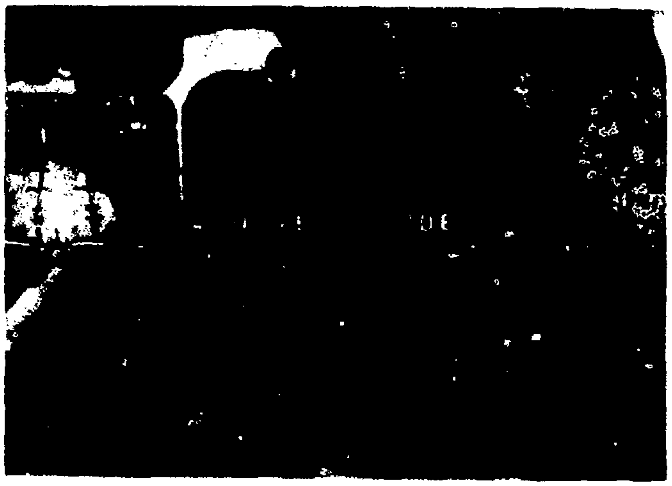


FIGURE E SELECTION OF A NEW DELIVERY MODE OPTION

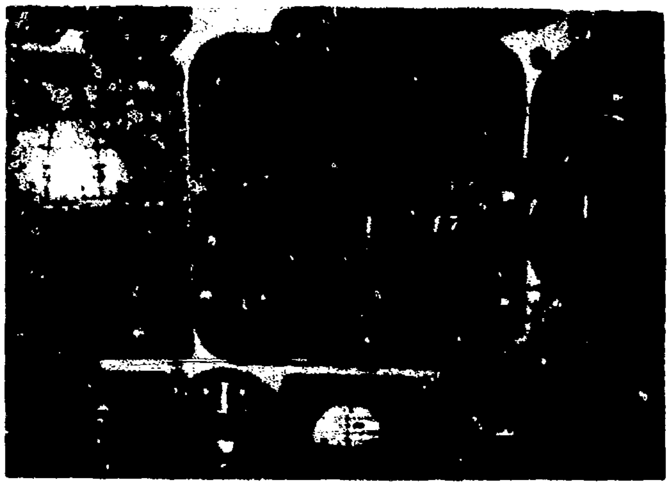


FIGURE F DELAY OPTIONS COMMENSURATE WITH THE NEW "MODE" SELECTION

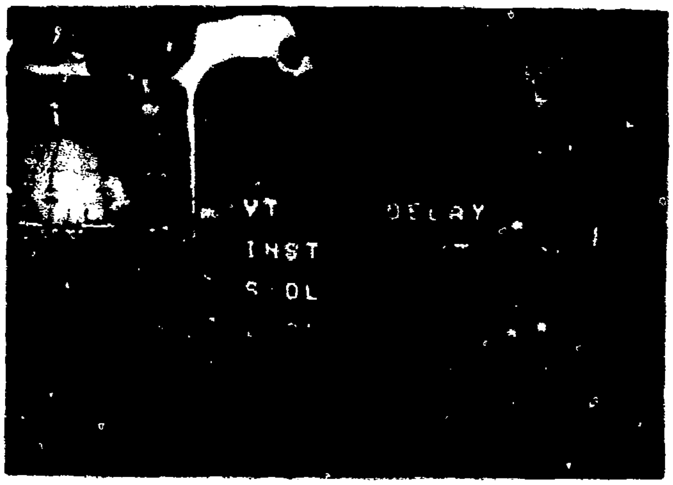


FIGURE G SELECTION OF A NEW DELAY OPTION

FIGURE H SUMMARY OF SELECTED OPTIONS

FIGURE I INITIATING A CHANGE IN FUZE SELECTION

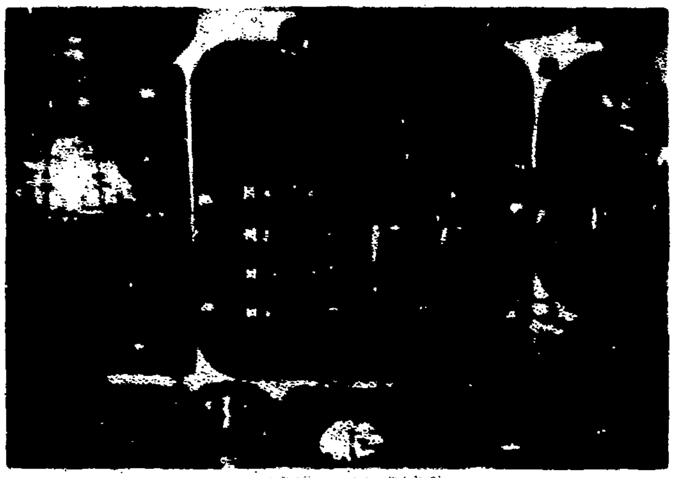


FIGURE J FUZE OPTIONS

FIGURE 9 PROGRAM CHANGE CYCLE (CONT)

With the programming sequence properly completed (as shown in Figure 7j) the pilot can do one of two things:

a. Release the weapon at the appropriate time by depressing the bomb release button without changing the AFFC settings, or

b. Effect a change in the AFFCS program by simply depressing that selection in the choice summary which he wishes to change, as shown in Figure 8a. Accordingly, the appropriate field will be displayed anew and the pilot selects the new MODE and DELAY options in the manner described above and depicted in Figures 8 and 9. Any one of the three fields (FUZE, MODE, DELAY) can be changed independently of the preceding fields in a similar manner. Changes can be implemented with the function switch left in ARM position without any safety hazards.

PRESENT STATUS

AFFCS

An exploratory development phase during FY 1974 led to fabrication of a developmental model of AFFCS which was flight tested China Lake during October 23 - November 9, 1973. The AFFCS was tested in conjunction with the RASS system and a model for the Advanced Modular Weapon bomb. Eight weapon drops and a total of approximately five hours of flight time resulted in a highly successful test with the AFFCS functioning properly, as per design, throughout the evaluation. A production version of the design is currently in an advanced engineering development phase.

A Joint Development Plan (JDP) for incorporation of the AFFCS into Air Force and Navy aircraft has been submitted in response to the JSOR for fuzes for Non-Propelled Conventional Weapons. In addition, the JDP is a response to the draft JSOR for Modular Weapons and the TSOR for Advanced General Purpose Bomb.

ADAPSAF

As a direct consequence of the AFFCS effort, a proposal has been submitted in response to the need generated by the Service Life Extension Program (SLEP) for the Navy's F4J aircraft, for an improved fuze function control and stores display set which will be compatible with existing and new fuzes during the life of the F-4 aircraft.

The proposal outlines the plan for obtaining an Adaptive Display and Programmer for Stores and Fuzes (ADAPSAF) concluding in a technical evaluation of 15 units. The ADAPSAF system will:

a. Display stores

b. Display fuze options

c. Continually verify correct system operation

d. Eliminate manual solenoid controls

e. Provide semi-automatic fuze programming

f. Have the capability to control existing and future air launched weapons without having to replace the control system itself. With two exceptions (absence of stores display capability and lack of solenoid controls), the AFFCS reflects the concepts and technology to be incorporated in the ADAPSAF system and can serve as a baseline model for the latter.

The proposed ADAPSAF system will display information on stores, control and display mechanical, electric and future fuzes in tail and nose well positions, control and display special fins and other related information.

It will also display information only on allowable delivery modes and fuze functioning delays for the /store/tail fuze/nose fuze/fins/other combinations. The pilot will automatically choose the proper fuze arming delay by choosing the allowable delivery mode.

The Adaptive Display and Programmer for Stores and Fuzes is shown diagramatically in Figure 10 with the hardware concept depicted in Figure 11. Operationally, it is quite similar to the AFFCS. The three principal components of the system are:

a. Cockpit Controls, comprised of the Cockpit Control Unit (CCU) and controls derived from the Weapon Control Panel. The CCU will display details of the carried stores and fuzes as well as allow for simplified control of retarding fins, and fuze arming and function delays. The CCU will be similar in size and panel organization to the control unit of the AFFCS.

b. The Mainframe Unit (MFU) situated in the avionics bay will contain all power supplies and power control circuits (function modules). The MFU outputs are programmed responses to commands received (via an interconnecting cable) from the CCU. The MFU will deliver the proper solenoid voltages when master ARM is selected and when the weapon release button is depressed. Likewise, the MFU will deliver the fuze arming voltages to the weapon racks. The various compartments of the MFU (shown in Figure 11) illustrate the modular design of the power supply section. Each compartment (module), in turn, is replaceable allowing for mechanical and electrical compatibility with any present or future air launched fuzed weapon system.

c. The Stores Information Unit (SIU), whose function is to allow the ordnanceman to feed stores information to the aircraft by setting a series of code switches on the SIU panel. The SIU panel, small in size and of inconsequential weight can readily be situated in one of several locations within the aircraft: the pilot's cockpit, the radar officer's cockpit, the avionics bay or even become an integral part of the mainframe package.

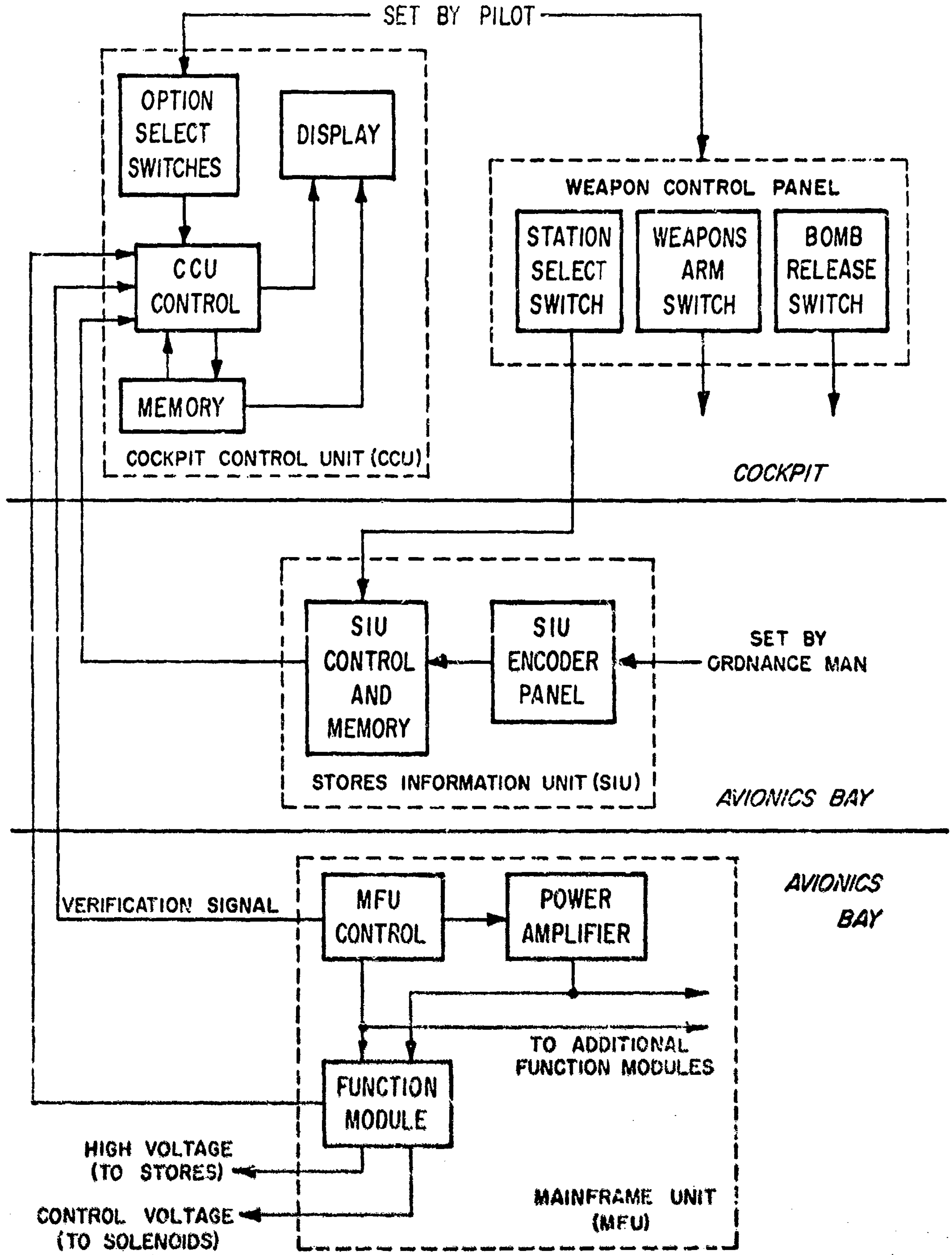


FIGURE 10 ADAPSAF—BLOCK DIAGRAM

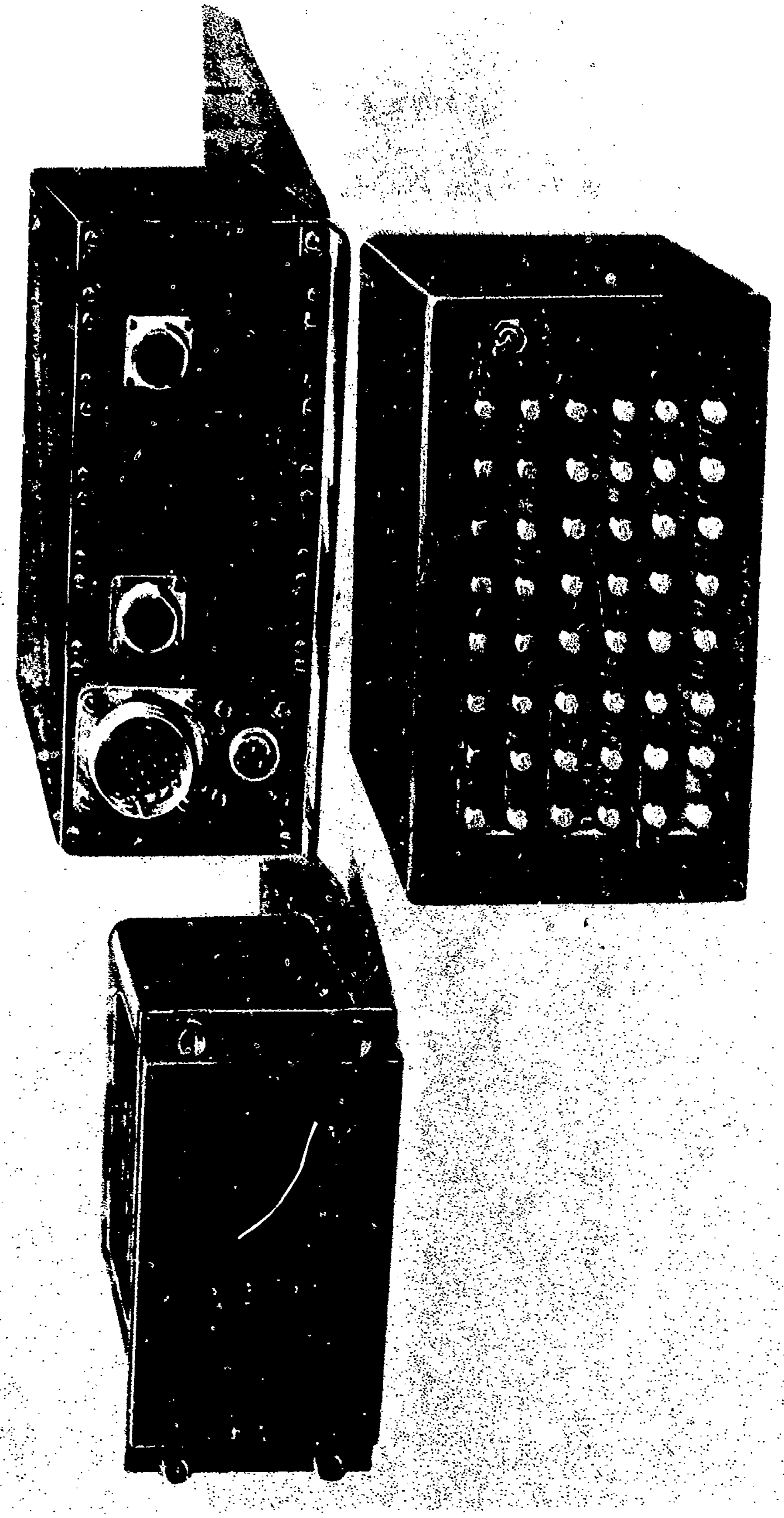


FIGURE 11 ADAPSAF - HARDWARE CONCEPT

FIGURES

TABLES

AUTOBIOGRAPHY

Mr. A. E. Pertman was born in 1941 in Russia and raised in Poland from 1945-1956. He received his secondary education in Breslau, Poland and in ORT Vocational High School in Israel. A naturalized U.S. citizen since 1963, he obtained a BSEE in 1965 and MSEE in 1969, both from the University of Maryland.

He has been employed by the Naval Surface Weapons Center (formerly Naval Ordnance Laboratory) in White Oak, Maryland since August 1965. His experience and expertise lie in definition and development of a broad variety of remote, unattended sensor systems. His present responsibilities include project and technical leadership in development of sensor systems.

Mr. Pertman is married and has three children, 8, 2, and 1 year old. He enjoys chess, reading and does a considerable amount of charitable work.

AIRCRAFT/STORES ELECTRICAL INTERFACE
COMPATIBILITY CONFORMATION
(U)
(Article Unclassified)

by

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ABSTRACT. (U) Aircraft/Stores compatibility is greatly effected by the electrical interface requirements of stores. A typical aircraft weapon station is often required to accommodate several types of electrically interfaced stores. Although these stores may be significantly different with respect to their tactical usage, a high degree of similarity can exist in their electrical interface requirements. To date, a time consuming manual comparative analysis had to be performed using hard copy aircraft stores management system design data and store electrical interface data to determine if the aircraft and store are electrically compatible. Because of the unwieldy nature and magnitude of the manual analysis, many times wiring for new stores has been added to the aircraft without trying to use available existing wiring. The Air Force Armament Laboratory has recently developed a computerized method for performing the required comparative analysis. This method uses an aircraft data base consisting of the aircraft stores management system electrical characteristics coded in such a manner that it can be used by the computer program. This data is compared against the store data file previously documented under the Stores Interface Definition and Analysis Program. This new computer program is designed to disclose any electrical incompatibilities that may exist between the aircraft and store selected for comparison. The computer printouts provide detail pin to pin and general interface compatibility information. Diagnostic message printouts are also provided to define each specific incompatibility condition that is detected. This new analysis system may be used to evaluate or verify the adequacy of an aircraft to control its existing store complement. The new computer analysis system described in this paper will greatly reduce the time and cost associated with analyzing aircraft and stores from an electrical compatibility standpoint.

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The improvements provided by this Phase 2 effort to Hi-Shear Corporation, Contract F08635-73-C-0094, significantly increased the analytical capability of the Stores Interface Data Handling Analysis System. It is now possible to perform complex aircraft/store electrical compatibility analyses without referring to numerous aircraft technical order manuals, wiring diagrams, and other related documents. The improved system will now facilitate the storage and processing of all relevant aircraft and store technical data. The Phase 2 effort also expanded the existing AFATL Store Data File Data Base to include additional characteristics that more precisely define the electrical composition and sequence of store interface signals. These new improvements, coupled with the existing Phase 1 stores interface data processing capability offer the user a valuable analytical tool that will aid in the following areas.

(1) Aircraft/Store Standard Interface Connector Development. The existing Phase 1 Store Data Files and computer programs enables the system user to determine standard aircraft/store electrical interface connectors and their pin function assignments for any combination of stores required to use the interface connection.

(2) Aircraft/Store Electrical Compatibility. The new Phase 2 aircraft data files and computer programs enables the system user to detect incompatibilities and/or verify the overall electrical compatibility between any existing or future aircraft (that are added to the data file) and any store documented in the AFATL Store Data File.

(3) New Store Development. The Phase 1 and 2 data files and computer programs will provide detail aircraft and store electrical data in a format that can be readily used (either manually or by computer means) by weapon system designers to develop new stores that have an electrical interface that will be common to a maximum of different type aircraft.

(4) Stores Management System Development. The existing Phase 1 comptuter programs, coupled with the expanded store data base, will enable the system user (with minor Phase 1 computer program modifications) to accurately determine the types and minimum quantities of interface circuits required for the universal (multi-store) management of stores from individual aircraft weapon stations.

(5) Technical Data Update and Maintenance. The nature of the computerized aircraft and store data files permits the efficient update of data. File updating (file card replacement) can be accomplished with very little effort, thus enabling the system to be maintained in a current status with a minimum expenditure of time and expense.

(6) Technical Data Dissemination. The new aircraft and modified store data files, with their respective data retrieval computer programs provides a rapid and low cost method to disseminate interface data in the form of computer printouts.

DATA PROCESSING SYSTEM DESCRIPTION

SYSTEM ARRANGEMENT: The new Aircraft Data Documentation formats and Computer Programs System Arrangement is shown in Figure 1. This arrangement was chosen because it provides a maximum of versatility for documenting and retrieving aircraft data for a variety of existing and future aircraft.

AIRCRAFT INTERFACE DATA DOCUMENTATION: Aircraft interface data is documented separately for each aircraft station. This approach compensates for any differences in aircraft stores management system equipment that may exist between the various aircraft stations.

Although one aircraft station may be equivalent to another with respect to store loading capability, both stations may not always be the same with regard to the type of interface circuit components used, or circuit switching logic employed. The aircraft station data documentation formats shown in Figure 1 are shown divided in two basic card sets. One card set is used to document the general (overall) station connector and wiring configuration for the respective station. The other card set is used to document detail aircraft electrical interface circuit provisions for each specific store and/or suspension device that is normally operated from the station. Consequently, thes card set will be comprised of a multiple of individual card sub-sets.

DOCUMENTATION FORMATS: A set of data documentation formats were developed and are provided to document electrical interface data for both existing and future aircraft. These formats are essentially computer punch card transcripts, and are used to document all the aircraft electrical characteristics required to facilitate a computerized aircraft/store interface compatibility analysis of both hardwired and multiplexed aircraft stores management systems. The basic function of each aircraft data documentation format is described in Table I.

FILE STRUCTURE: It is expected that a set of data documentation formats will be prepared for each different aircraft. These data will then be keypunched on to computer punch cards. Once in card form, the individual aircraft card deck data may be used and stored in this form, or transferred to tape or any other suitable digital data storage and handling means.

REVISED STORE DATA FILE DESCRIPTION: The existing AFATL store data file structure had to be modified to facilitate operation of the new aircraft/store interface compatibility computer programs. Essentially, the original store data file was expanded to include additional electrical interface characteristic data. These data were required to permit a complete and accurage means to test aircraft/store compatibility. The modified data file structure, including a brief description of the supplemental and new store data documentation formats, is described in Table II.

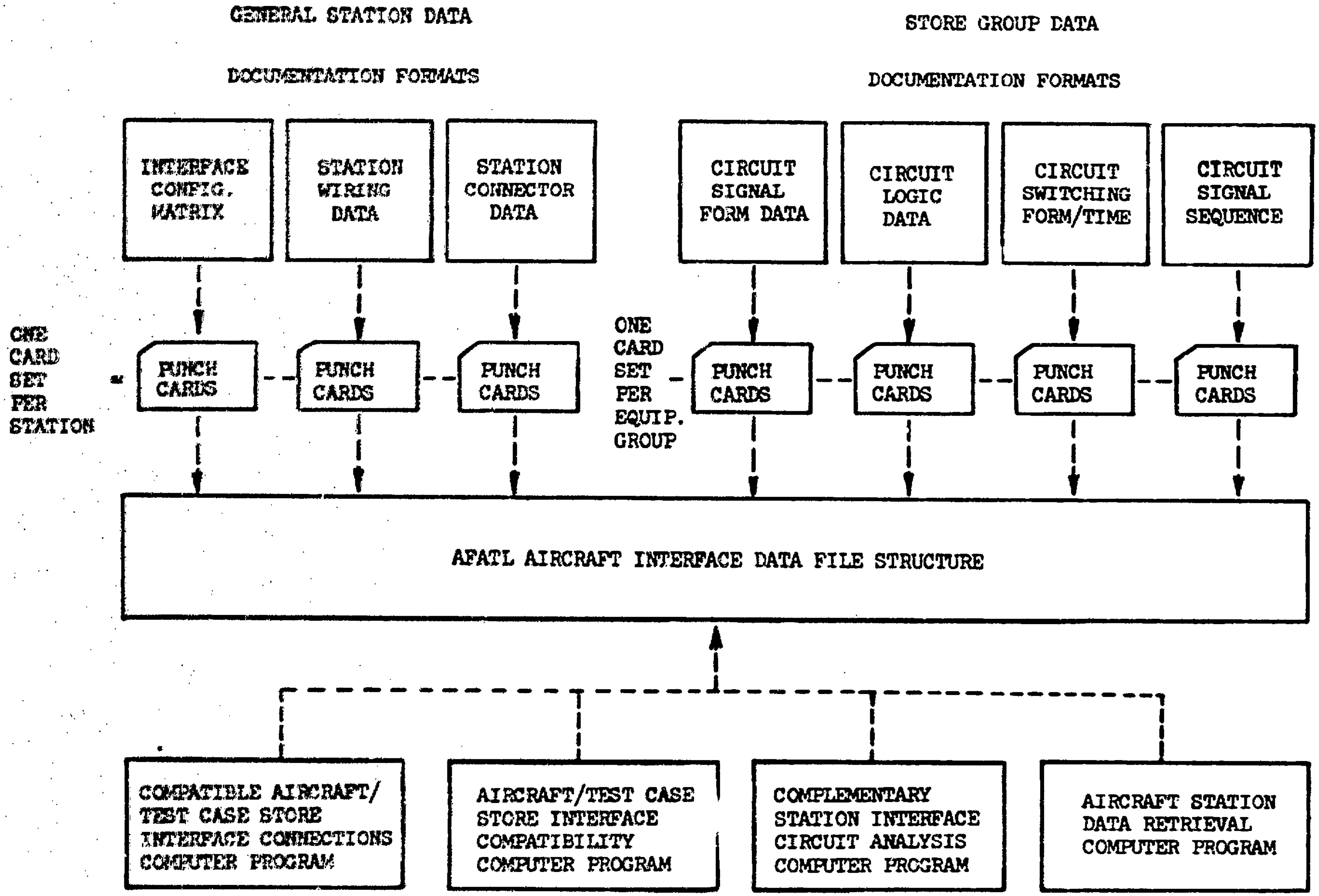

Figure 1. AFATL Aircraft Interface Data File and Computer Programs

TABLE I. AIRCRAFT DATA DOCUMENTATION FORMATS AND FUNCTIONS

	Documentation Format	Function
1.	Aircraft Interface Configuration Code Conversion Matrix	Used to define and record applicability of stores to aircraft station interface connections.
2.	Station Interface Connector Characteristics Data	Used to record connector type, function and pin utilization details for all connectors associated with the respective aircraft station.
3.	Station Interface Circuit Wiring Characteristics Data	Used to record the general wiring configuration of all aircraft station/store interface wiring provisions.
4.	Aircraft Circuit Signal Form Characteristics Data	Used to define and record the electrical composition of all aircraft circuits associated with the management of a specific store type.
5.	Aircraft Circuit Signal Logic Characteristics Data	Used to define and record the basic operational usage and switching logic of all aircraft circuits associated with the management of a specific store type.
6.	Aircraft Circuit Signal Switching Form/Time Characteristics Data	Used to define and record the switching method and timing sequence of each applicable aircraft circuit associated with the management of a specific store type.
7.	Aircraft Circuit Signal Sequence Characteristics Data	Used to define and record the signal sequence order and on/off relationship of all aircraft circuits associated with the management of a specific store type.

TABLE II. MODIFIED AFATL STORE DATA DOCUMENTATION FORMAT AND FUNCTIONS

	Documentation Format	Function
1.	Equipment Introductory/ Connector (Existing Format)	Unchanged, used to record store interface connector details for individual stores.
2.	Supplemental Introductory/ Connector (New Format)	Used to document additional data for aircraft/store connector matching purposes.
3.	Equipment Signal Form (Existing Format)	Unchanged, used to define and record the electrical composition of interface circuits peculiar to an individual store.
4.	Supplemental Equipment Signal Form (New Format)	Used to document additional signal form characteristics that further define the composition and tolerance values of interface circuits peculiar to an individual store.
5.	Equipment Signal Logic (Existing Format)	Unchanged, used to define and record store input switching logic requirements of interface circuits peculiar to an individual store.
6.	Supplemental Equipment Signal Logic (New Format)	Used do document additional signal logic, and define the circuit operation function (use) of interface circuits peculiar to an individual store.
7.	Equipment Switching Form/ Time (New Format)	Used to define and record the switching method and timing sequence required by each interface circuit peculiar to an individual store.
8.	Equipment Signal Sequence (New Format)	Used to define and record the signal sequence and on/off relationship requirements of all interface circuits associated with, and peculiar to, an individual store.

FILE STRUCTURE: The modified store data file structure was designed to facilitate operation of both the new aircraft/store interface compatibility programs and those store electrical analysis computer programs described in AFATL-TR-73-214, Phase I. The Phase I Store Electrical Analysis Computer Programs were modified only to the extent required to permit reading of the modified store data file. New store characteristics data is not used or processed by these existing programs.

ELECTRICAL INTERFACE ANALYSIS COMPUTER PROGRAM: Three computer programs are provided for aircraft/store electrical interface compatibility analysis purposes. These new computer programs will test the aircraft against any equipment that exists in, or may be added to the AFATL Store Data File. The compatible Aircraft/Test Case Store Interface Connections Computer Program provides a means to determine aircraft/store electrical interface compatibility by comparing the mating ability of the aircraft and test case store interface connectors. A test case store is defined as the store or suspension device that is to be tested for compatibility with the aircraft interface. The Aircraft/Test Case Store Interface Compatibility Computer Program essentially performs a pin to pin circuit compatibility analysis for all associated aircraft/store interface connections. The program provides a diagnostic printout of any incompatibility that may exist that will preclude satisfactory electrical compatibility between the aircraft and the store. The complementary station interface circuit analysis computer program provides a means to determine electrical interface compatibility independent of the aircraft to store connector mating ability. Thus, this program will facilitate the analysis and definition of all complementary (matched) circuits that exist between the test case store and any one (selected), or all aircraft station interface connections. An Aircraft Station Data Retrieval Computer Program is also provided to retrieve any part of, or all data documented in the aircraft interface data file. All of the aforementioned computer programs are written in the FORTRAN computer language and are functional (without change) for any type of aircraft that may be documented on the new universal aircraft data documentation formats.

COMPATIBLE AIRCRAFT/TEST CASE STORE INTERFACE CONNECTIONS COMPUTER PROGRAM: This computer program is designed to search the aircraft data file and determine what aircraft interfaces are compatible with a selected test case store with respect to physical connector(s) mating ability. After these compatible aircraft interface connections are identified, the user may then use this information to select the appropriate aircraft interface(s) for a detailed pin to pin, or circuit electrical interface compatibility analysis. Other analytical computer programs are provided by the data processing system for this purpose. The general arrangement of the Compatible Aircraft/Test Case Store Interface Connections Computer Program is depicted in Figure 2.

A computer control (input) card deck is used in conjunction with the new Aircraft Interface Data File and modified AFATL Store Data File

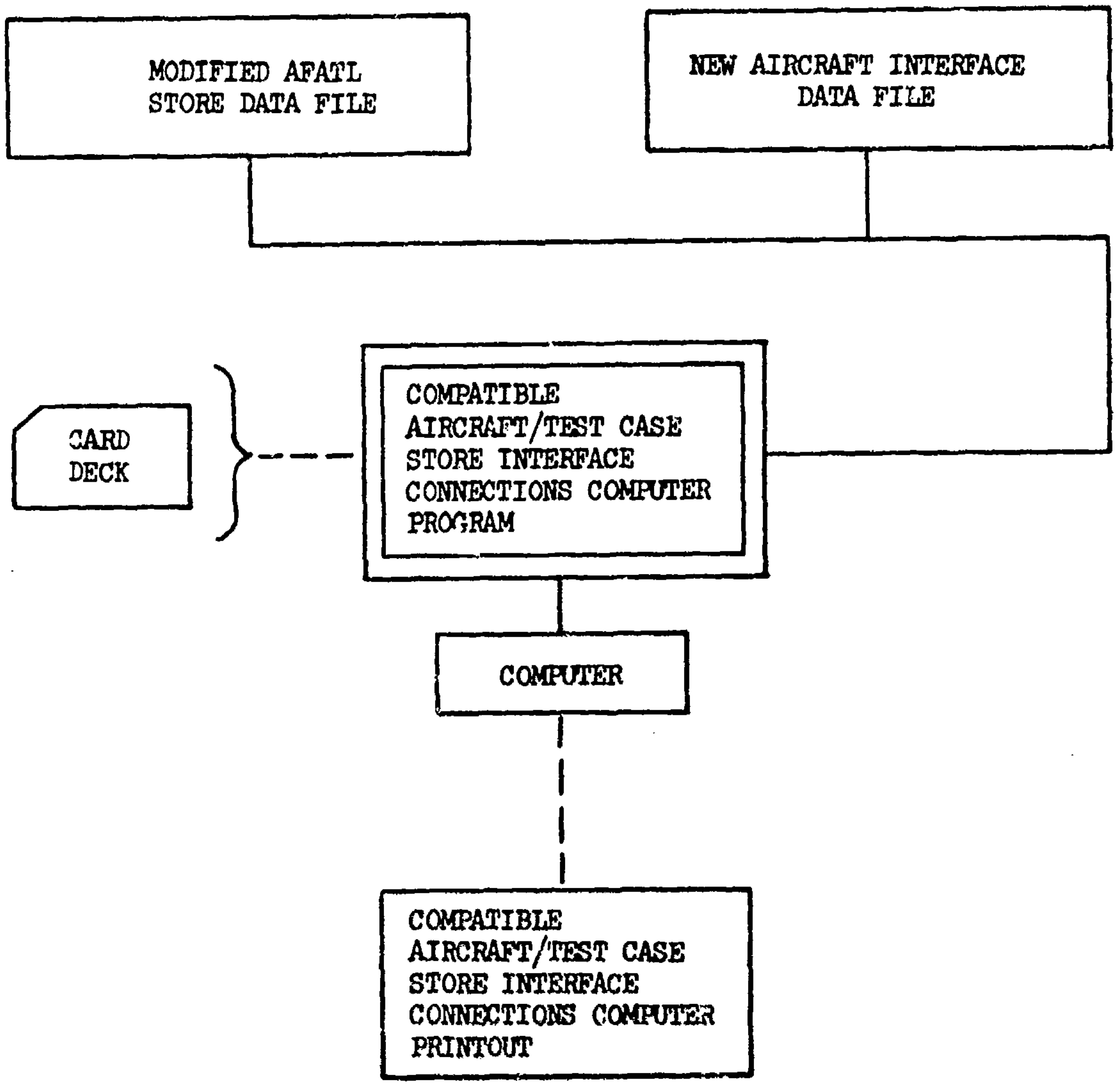

Figure 2. Compatible Aircraft/Test Case Stores
Interface Connections Computer Program

to provide the following program control features.

a. Select the desired test case store and/or suspension device for aircraft interface compatibility testing.

b. Select the aircraft station(s) and all aircraft interface connections that are to be examined (any one, a combination, or all).

The computer program will produce a data printout (Figure 3) that will identify all aircraft interface connections (that are compatible with the test case store) by aircraft interface connection code number and connector(s) part number. This printout will also specify all store types and their connector(s) part numbers that are normally controlled by the respective aircraft interface connection. The printout will identify all selected aircraft interface connections that are not physically compatible with the test case store by an appropriate diagnostic message. A record of the requested data will also be included on the printout.

AIRCRAFT/TEST CASE STORE INTERFACE COMPATIBILITY COMPUTER PROGRAM: This computer program is designed to perform a detailed interface circuit compatibility analysis between all selected (and physically compatible) aircraft interface connections and the selected test case store. Essentially, this program compares the corresponding aircraft and store circuit characteristics of both sides of the interface. Each interface pin to pin connection is evaluated in one or more electrical characteristic comparison modes. Each mode determines compatibility based on different interface function criteria. The function criteria of each characteristic comparison mode is described in Table III. This method of circuit comparison adds versatility to the system to allowing the user to analyze data for only those interface compatibility functions (modes) applicable to his particular needs. The general arrangement of the Aircraft/Test Case Store Interface Compatibility Program is depicted in Figure 4.

A computer control (input) card deck is used in conjunction with the new Aircraft Interface Data File and modified AFATL Store Data File to provide the following program control features.

a. Select the desired test case store and/or suspension device for aircraft interface compatibility testing.

b. Select the aircraft station(s) and all aircraft interface connections that are to be examined (any one, a combination, or all).

c. Select the characteristic comparison modes to be used in the analysis (any one, a combination, or all).

d. Select the desired computer printouts.

COMPATIBLE AIRCRAFT/TEST CASE STORE ELECTRICAL INTERFACE CONNECTIONS

STATION NO.: 1

INTERFACE CONNECTION NO. 1
TEST CASE STORE: CBU-XX(MS-3102A-14-5P)
TEST CASE SUSPENSION DEVICE: NONE REQUESTED FOR EXAMINATION

AIRCRAFT CONNECTOR IDENT.	AIRCRAFT CONNECTOR PART NO.	EQUIPMENT INTERFACE GROUP	EXISTING COMPATIBLE STORES (CONNECTOR THAT ARE CONTROLLED BY THE RESPECTIVE AIRCRAFT INTERFACE)
053	MS3108A-14S-5S	01-001-XX	CBU-XA(MS3102A-14-5P) . . . . . . .CBU-XB(MS3102A-14-5P)
057	MS3108A-14S-5S	01-002-XX	LAU-XA(AN3102A-14-5P) . . . . . . .LAU-XB(MS3102A-14-5P)
058	MS3108A-14S-5S	01-003-XX	TWJ-XA(MS3102A-14-5P)

INTERFACE CONNECTION NO. 2

(ADDITIONAL INTERFACE CONNECTOR DATA WILL BE PRINTED OUT IF THE TEST CASE STORE REQUIRES MORE THAN ONE CONNECTION TO THE AIRCRAFT.)

Figure 3. Sample Output For Compatible Aircraft/Test Case Store Interface Connections Program.

TABLE III CIRCUIT CHARACTERISTIC COMPARISON MODES

	Comparison Mode	Function
1.	Interface Wiring	Determine if the aircraft and test case store are compatible with respect to basic wiring installation requirements.
2.	Signal Category	Determine if the signal category assigned to each aircraft interface connection circuit is compatible with the category assigned to the mating test case store circuit.
3.	Signal Form	Determine if all circuits available at the aircraft interface connection can suitably control the test case store from an electrical power standpoint.
4.	Signal Logic	Determine if all circuits available at the aircraft interface connection can suitably control the test case store from a switching logic and operational usage standpoint.
5.	Switching Form/Time	Determine if all circuits available at the aircraft interface connection can suitably control the test case store from a switching method and timing sequence standpoint.
6.	Signal Sequence	Determine if all circuits available at the aircraft interface connection can suitably control the test case store with respect to its signal switching sequence order and related on/off signal requirements.

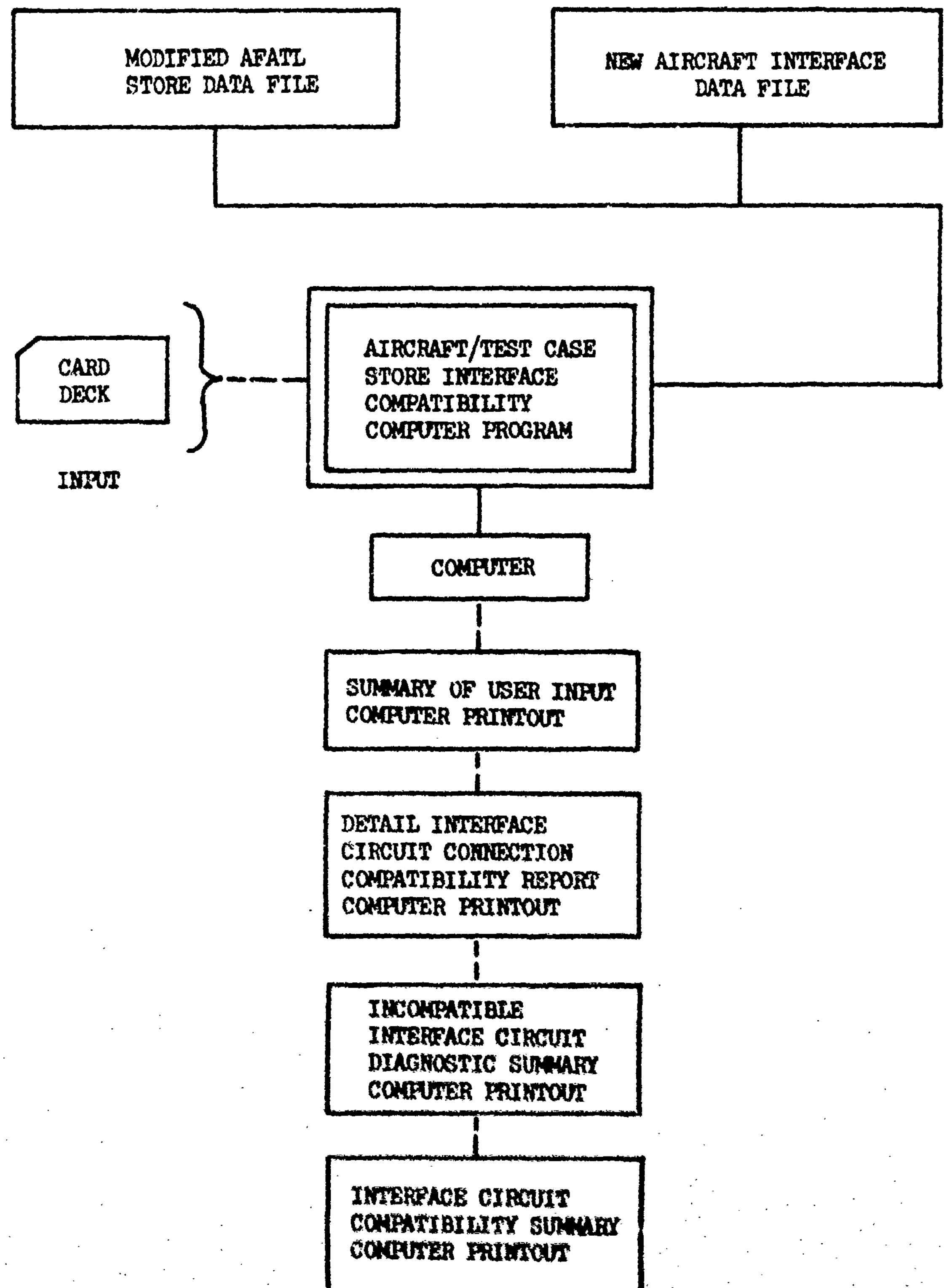

Figure 4. Aircraft/Test Case Store Interface Compatibility Program

The computer program will produce the following series of computer printouts (Figures 5 through 8).

a. Summary of User Input. This computer printout provides a record of all the data requested by the user.

b. Detail Interface Circuit Connection Compatibility Report. This computer printout provides a listing of all interface connections that exist between the aircraft and test case store. Each aircraft circuit is identified by a circuit code number and its signal function nomenclature. The corresponding store (pin mate) is identified by its interface connector code number and pin letter. The store circuit is also identified by its signal function nomenclature. The compatibility of each connection is indicated separately for each circuit characteristic comparison mode. A YES in an adjacent characteristic comparison mode column indicates that the respective interface connection (aircraft and store) are compatible. A NO indicates incompatibility of the interface connection.

c. Incompatible Interface Circuit Diagnostic Printout. This computer printout complements the detail interface circuit connection compatibility report and provides a listing of all incompatible interface connections. Each incompatible connection is identified by test case store connector/pin number and corresponding aircraft circuit number. A diagnostic message will be printed out separately for each incompatible connection. The message will identify the data file (aircraft and store) characteristics numbers examined and describe the incompatible condition(s).

d. Interface Circuit Compatibility Summary. This computer printout provides a quick reference that summarizes the compatibility of all selected aircraft station interface connections with the test case store. The printout will list all interface connections by aircraft interface connection code number. Each aircraft connection is correlated with each circuit characteristic comparison mode. A YES in the respective characteristic comparison mode column indicates that all interface circuits examined for that particular aircraft interface connection are compatible with the test case store. A NO indicates that one or more aircraft circuits are not compatible due to a circuit connector mating discrepancy, and/or a circuit electrical characteristic incompatibility.

COMPLEMENTARY STATION INTERFACE CIRCUIT ANALYSIS PROGRAM. This computer program is designed to determine aircraft/store electrical compatibility by examining individual interface circuit electrical characteristics independent of the aircraft and test case store connector type and pin insert configurations. This feature will permit a detailed and complete interface circuit comparison between any aircraft and store interface stored in the respective system data files.

```
AIRCRAFT/TEST CASE STORE INTERFACE COMPATIBILITY PROGRAM

    ***  SUMMARY OF USER INPUT  ***

 AIRCRAFT                          F-111A F-B
 STATION NUMBER                     4
 TEST CASE STORE                   TER-9-111      (110205)
 TEST CASE SUSPENSION DEVICE       NONE

 SELECTED EQUIPMENT INTERFACE GROUPS

    4-  4- 0

 SELECTED SORTING MODES

      INTERFACE WIRING   YES
      SIGNAL CATEGORY    YES
      SIGNAL FORM        YES
      SIGNAL LOGIC       YES
      SWITCHING F/T      YES
      SIGNAL SEQUENCE    YES

 SELECTED REPORTS

      DETAIL INTERFACE CIRCUIT COMPATIBILITY          YES
      INCOMPATIBLE INTERFACE CIRCUIT DIAGNOSTIC       YES
      INTERFACE CIRCUIT COMPATIBILITY SUMMARY         YES
```

Figure 5 Sample Output for the User Input Report

```
AIRCRAFT/TEST CASE STORE INTERFACE COMPATIBILITY PROGRAM

    ***  SUMMARY OF USER INPUT  ***

 AIRCRAFT                         F-111A F-B
 STATION NUMBER                    4
 TEST CASE STORE                  TER-9-F4       (110203)
 TEST CASE SUSPENSION DEVICE      NONE

 SELECTED EQUIPMENT INTERFACE GROUPS

    4-  4- 0

 SELECTED SORTING MODES

    INTERFACE WIRING   YES
    SIGNAL CATEGORY    YES
    SIGNAL FORM        YES
    SIGNAL LOGIC       YES
    SWITCHING F/T      YES
    SIGNAL SEQUENCE    YES

 SELECTED REPORTS

    DETAIL INTERFACE CIRCUIT COMPATIBILITY          YES
    INCOMPATIBLE INTERFACE CIRCUIT DIAGNOSTIC       YES
    INTERFACE CIRCUIT COMPATIBILITY SUMMARY         YES
```

Figure 5 Continued

DETAIL INTERFACE CIRCUIT CONNECTION COMPATIBILITY REPORT

AIRCRAFT F-111A F-B   STATION NO. 4   PAGE 1

EQUIPMENT GROUP 4- 4- 0

TEST CASE STORE TER-9-111

A/C INTERFACE CONNEXION		TEST STORE CONNECTION		COMPATIBLE CKT. CHARS.					
AIRCRAFT CIRCUIT NUMBER	CIRCUIT FUNCTION	CONNECT IDENT & PIN REF	STORE CIRCUIT FUNCTION	INT WIR	SIG CAT	SIG FRM	SIG LOG	SHT F/T	SIG SEQ
4-300	STORE IDENT 1	29- 1	F111 ST ID 1(O)	YES	YES	YES	YES	YES	YES
4-301	NOSE ARM SEL	29- 2	NOSE ARM	YES	YES	YES	YES	YES	YES
4-302	TAIL ARM SEL	29- 3	TAIL ARM	YES	YES	YES	YES	YES	YES
4-303	RACK CONT PWR	29- 4	28VDC BUS	YES	YES	YES	YES	YES	YES
4-304	OPT J-USP SEL	29- 6	SEL ROCKETS	YES	YES	YES	YES	YES	YES
4-305N	GROUND	29- 7	GROUND	YES	YES	YES	YES	YES	YES
4-306A	SINGLE FIRE	29- 8	STEP/FIRE	YES	YES	YES	YES	YES	YES
4-306B	STORE JETTISON	29- 8	STEP/FIRE	YES	YES	YES	YES	YES	YES
4-307	STORE IDENT 3	29-13	F111 C3U EMP(O)	YES	YES	YES	YES	YES	YES
4-308	STORE IDENT 4	29-11	F111 STA TRN(O)	YES	YES	YES	YES	YES	YES
4- -J	NO CKT	29- 5	F4 STA TRANS	YES	YES	YES	YES	YES	YES
4-309	ARM PWR INTRLOK	29- 9	111 ARM INLK(O)	YES	YES	YES	YES	YES	YES
4- -J	NO CKT	29-12	NO CIRCUIT	YES	YES	YES	YES	YES	YES

Figure 6 Sample Output for the Detail Interface Circuit Connection Compatibility Report

DETAIL INTERFACE CIRCUIT CONNECTION COMPATIBILITY REPORT

AIRCRAFT F-111A F-8 STATION NO. 4 PAGE 1

EQUIPMENT GROUP 4- 4- 0

TEST CASE STORE TER-9-F4

A/C INTERFACE CONNEXION		TEST STORE CONNECTION		COMPATIBLE CKT. CHARS.					
AIRCRAFT CIRCUIT NUMBER	CIRCUIT FUNCTION	CONNECT IDENT & PIN REF	STORE CIRCUIT FUNCTION	INT WIR	SIG CAT	SIG FRM	SIG LOG	SMT F/T	SIG SEQ
4-[illegible]	STORE IDENT 1	29- 1	F4 CRU EMPTY(O)	YES	YES	YES	YES	YES	YES
4-[illegible]	NOSE ARM SEL	29- 2	NOSE ARM	YES	YES	YES	YES	YES	NO
4-[illegible]	TAIL ARM SEL	29- 3	TAIL ARM	YES	YES	YES	YES	YES	NO
4-30[illegible]	RACK CONT PWR	29- 4	2AVOC BUS	YES	YES	YES	YES	YES	YES
4-30[illegible]	OPT 3-DSP SEL	29- 6	SEL ROCKETS	YES	YES	YES	YES	YES	NO
4-305N	GROUND	29- 7	GROUND	YES	YES	YES	YES	YES	NO
4-306A	SINGLE FIRE	29- 5	STEP/FIRE	YES	YES	YES	YES	YES	YES
4-306B	STORE JETTISON	29- 8	STEP/FIRE	YES	YES	YES	YES	YES	NO
4-307	STORE IDENT 3	29-10	F111 CRU EMP	YES	YES	YES	YES	YES	NO
4-308	STORE IDENT 4	29-11	F111 STA TRN	YES	YES	YES	YES	YES	YES
4- -C	NO CKT	29- 5	F4 STA TRANS(O)	NO	NO	NO	NO	NO	NO
4-309	ARM PWR INTRLOK	29- 9	F111RACK PRS	YES	YES	YES	YES	YES	YES
4- -8	NO CKT	29-12	NO CKT	YES	YES	YES	YES	YES	YES

Figure 6 Continued

INCOMPATIBLE INTERFACE CIRCUIT DIAGNOSTIC SUMMARY

AIRCRAFT F-111A F-8 STATION NO. 4 PAGE 1

EQUIPMENT GROUP 4- 4- 0

TEST CASE STORE TER-9-111

TEST CASE STORE CONNECTOR	AIRCRAFT CIRCUIT NUMBER	INCOMPATIBLE CIRCUIT CHARACTERISTICS (A/C AND STORE CHAR. NOS. & DIAGNOSTIC MESSAGE)
29- 1	4-300	NONE - ALL CHARACTERISTICS COMPATIBLE
29- 2	4-301	NONE - ALL CHARACTERISTICS COMPATIBLE
29- 3	4-302	NONE - ALL CHARACTERISTICS COMPATIBLE
29- 4	4-303	NONE - ALL CHARACTERISTICS COMPATIBLE
29- 6	4-304	NONE - ALL CHARACTERISTICS COMPATIBLE
29- 7	4-305N	NONE - ALL CHARACTERISTICS COMPATIBLE
29- 8	4-306A	NONE - ALL CHARACTERISTICS COMPATIBLE
29- 8	4-306B	NONE - ALL CHARACTERISTICS COMPATIBLE
29-10	4-307	NONE - ALL CHARACTERISTICS COMPATIBLE
29-11	4-308	NONE - ALL CHARACTERISTICS COMPATIBLE
29- 5		NONE - INTERFACE PIN CONNECTION NOT USED BY AIRCRAFT OR TEST CASE STORE
29- 9	4-309	NONE - ALL CHARACTERISTICS COMPATIBLE
29-12		NONE - INTERFACE PIN CONNECTION NOT USED BY AIRCRAFT OR TEST CASE STORE

Figure 7 Sample Output for the Incompatible Interface Circuit Diagnostic Report

INCOMPATIBLE INTERFACE CIRCUIT DIAGNOSTIC SUMMARY

AIRCRAFT F-111A F-8 STATION NO. 4 PAGE 1

EQUIPMENT GROUP 4- 4- 5

TEST CASE STORE TER-9-F4

TEST CASE STORE CONNECTOR	AIRCRAFT CIRCUIT NUMBER	INCOMPATIBLE CIRCUIT CHARACTERISTICS (A/C AND STORE CHAR. NOS. & DIAGNOSTIC MESSAGE)	
29- 1	4-300	(A60A-F755) THE AIRCRAFT MONITOR CIRCUIT LOGIC IS NOT SUITABLE TO DISPLAY OR CONTROL THE AVAILABLE OPTIONAL STORE MONITOR CIRCUIT	
29- 2	4-301	(A602-F6021) THE TEST CASE STORE CIRCUIT ON-STATE (TRUE) REQUIREMENTS ARE NOT COMPATIBLE WITH RELATED AIRCRAFT CIRCUITS	1
29- 3	4-302	(A602-F6021) THE TEST CASE STORE CIRCUIT ON-STATE (TRUE) REQUIREMENTS ARE NOT COMPATIBLE WITH RELATED AIRCRAFT CIRCUITS	1
29- 4	4-303	NONE - ALL CHARACTERISTICS COMPATIBLE	
29- 6	4-304	(A602-F6021) THE TEST CASE STORE CIRCUIT ON-STATE (TRUE) REQUIREMENTS ARE NOT COMPATIBLE WITH RELATED AIRCRAFT CIRCUITS	1
29- 7	4-305M	NONE - ALL CHARACTERISTICS COMPATIBLE	
29- 8	4-306A	(A602-F6021) THE TEST CASE STORE CIRCUIT ON-STATE (TRUE) REQUIREMENTS ARE NOT COMPATIBLE WITH RELATED AIRCRAFT CIRCUITS	1
29- 8	4-306B	(A602-F6021) THE TEST CASE STORE CIRCUIT ON-STATE (TRUE) REQUIREMENTS ARE NOT COMPATIBLE WITH RELATED AIRCRAFT CIRCUITS	1
29-10	4-307	NONE - INTERFACE PIN CONNECTION NOT USED BY TEST CASE STORE	
29-11	4-308	NONE - INTERFACE PIN CONNECTION NOT USED BY TEST CASE STORE	
29- 5		(A200A-E150A) NO CIRCUIT EXISTS IN AIRCRAFT TO MATE WITH ACTIVE TEST CASE STORE INTERFACE CONNECTION	
		(A631-C6011) AIRCRAFT CIRCUIT GROUND/SHIELD CONNECTION IS NOT COMPATIBLE WITH THE SIGNAL FUNCTION INTERFACE REQUIREMENTS OF THE TEST CASE STORE	
29- 9	4-309	NONE - INTERFACE PIN CONNECTION NOT USED BY TEST CASE STORE	
29-12		NONE - INTERFACE PIN CONNECTION NOT USED BY AIRCRAFT OR TEST CASE STORE	

Figure 7 Continued

INTERFACE CIRCUIT COMPATIBILITY SUMMARY

AIRCRAFT F-111A F-B
TEST CASE TORE TER-9-111 STATION NO. 4

A/C INTERFACE CONNECTION

EQUIPMENT GROUP	--- COMPATIBLE CIRCUIT CHARACTERISTICS ---					
	INTERF. WIRING	SIG. CAT.	SIG. FORM	SIG. LOGIC	SWITCH F/T	SIGNAL SEQUENCE
4- 4- 0	YES	YES	YES	YES	YES	YES

Figure 8 Sample Output for the Interface Circuit Compatibility Summary Report

INTERFACE CIRCUIT COMPATIBILITY SUMMARY

AIRCRAFT F-111A F-B STATION NO. 4
TEST CASE STORE TER-9-F4

A/C INTERFACE CONNECTION EQUIPMENT GROUP	--- COMPATIBLE CIRCUIT CHARACTERISTICS --- INTERF. WIRING	SIG. CAT.	SIG. FORM	SIG. LOGIC	SWITCH F/T	SIGNAL SEQUENCE
4- 4- 0	NO	NO	NO	NO	.0	NO

Figure 8 Continued

The New Complementary Station Interface Circuit Analysis Program will, therefore, detect, compare, and facilitate the printout of all those aircraft interface circuits that will complement (are electrically compatible with) the selected test case store. This new computer program will also be capable of selectively testing the interface(s) in any one or all of the circuit comparison modes described in Table III. However, the signal sequence comparison mode will not be included in the analysis. This mode requires that both the aircraft and store interface connections (for all circuits) be arranged in a compatible pin insert configuration. The general arrangement of the Complementary Station Interface Circuit Analysis Program is depicted in Figure 9.

A computer control (input) card deck is used in conjunction with the new Aircraft Interface Data File and modified AFATL Store Data File to provide the following program control features.

a. Select the desired test case store and/or suspension device for aircraft interface compatibility testing.

b. Select the aircraft station(s) and all aircraft interface connections that are to be examined (any one, a combination, or all).

c. Select the circuit characteristic comparison modes to be used in the analysis (any one, a combination, or all).

The computer program will produce the following computer printouts (Figures 10 and 11).

a. Summary of User Input. This computer printout provides a record of all the data requested by the user.

b. Complementary Station Interface Circuit Analysis Report. This computer printout provides a listing of all aircraft circuits that are compatible with each pin connection on the selected test case store. The printout will identify the connector identification and pin reference of each test case store circuit. The complementary aircraft circuits detected by the program will be identified by interface connection number, aircraft circuit function number, connector identification and pin reference. These data will be listed adjacent to the respective test case store circuit. A complementary aircraft circuit will be specified only if all the detail aircraft circuit electrical characteristics within each selected circuit characteristic comparison mode complements the respective store circuit.

DATA RETRIEVAL PROGRAMS.

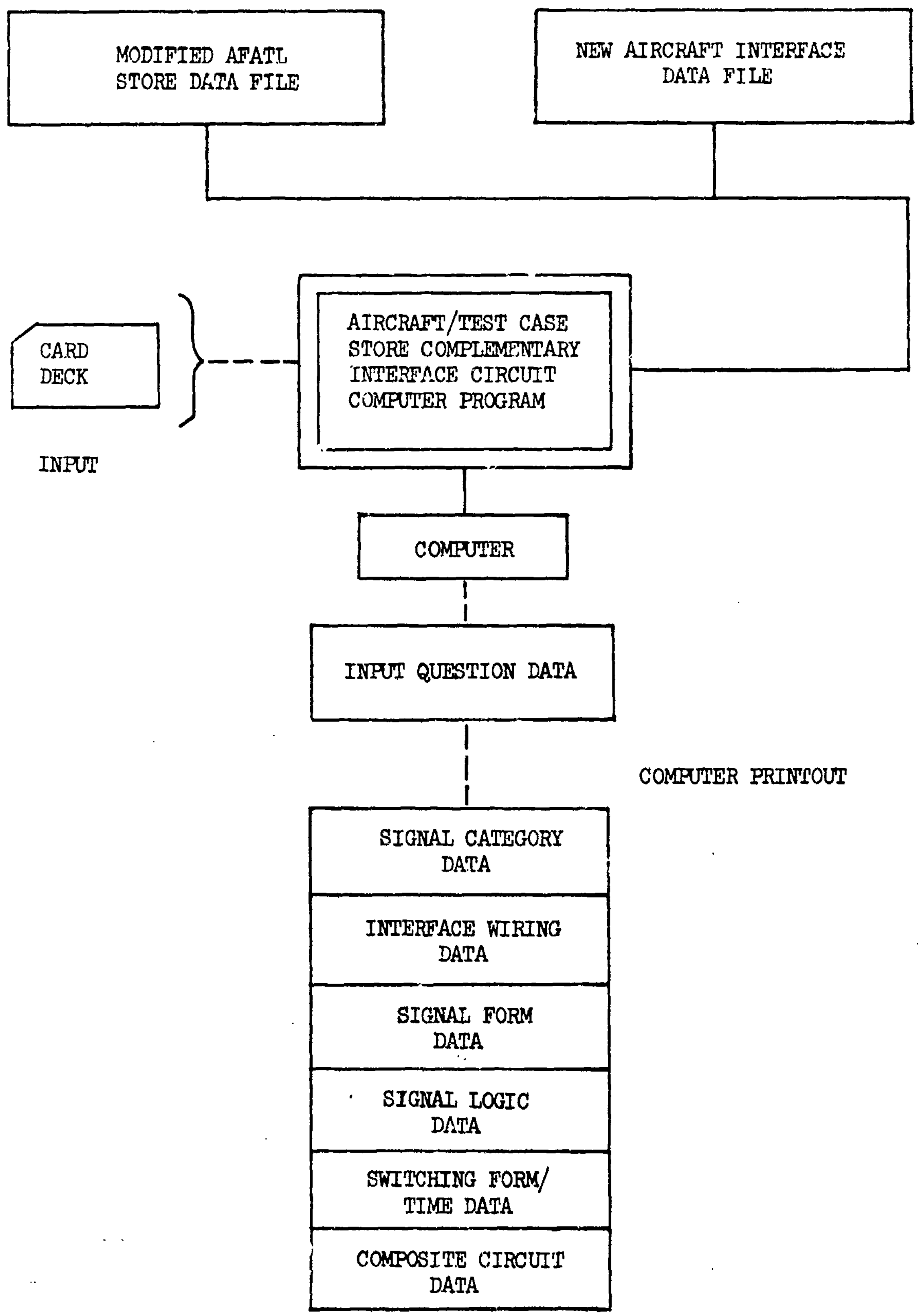

Figure 9. Aircraft/Test Case Store Complementary Station Interface Circuit Analysis Program

```
COMPLEMENTARY STATICN INTERFACE CIRCUIT ANALYSIS PROGRAM

    *** SUMMARY OF USER INPUT ***

 AIRCRAFT                              F-111A
 STATION NUMBER                          4
 TEST CASE STORE                       LAU-88A          (100127)
 TEST CASE SUSPENSION DEVICE           NONE

 SELECTED EQUIPMENT INTERFACE GROUPS

    4-  4- 0    4-  5- 0

 SELECTED SORTING MODES

   INTERFACE WIRING   YES
   SIGNAL CATEGORY    YES
   SIGNAL FORM        YES
   SIGNAL LOGIC       NO
   SWITCHING F/T      NO
```

Figure 10 Sample Output of the User Input Report

```
                COMPLEMENTARY STATION INTERFACE CIRCUIT ANALYSIS REPORT
     STATION NO.  4  OF AIRCRAFT F-111A                              PAGE    1
       CIRCUIT CHAR. SORTING MODE - COMPOSITE - WIRNG CATEG S.F.
       TEST CASE STORE    LAU-88A

   TEST CASE STORE
   CONNECTOR IDENT                  COMPLEMENTARY AIRCRAFT CIRCUITS
    AND PIN REF.         (EQ.GRP. NO. & A/C CKT FN NO. & CONN.IDENT & PIN REF)

     114- B             NO COMPLEMENTARY AIRCRAFT CIRCUITS FOUND

     114- C             NO COMPLEMENTARY AIRCRAFT CIRCUITS FOUND

     114- D             NO COMPLEMENTARY AIRCRAFT CIRCUITS FOUND

     114- F              4-  5- 0, 4-200 (927- G )    4-  5- 0, 4-201 (927- C )
                         4-  5- 0, 4-202 (927- R )    4-  5- 0, 4-203 (927- B*)
                         4-  5- 0, 4-216 (927- P )    4-  4- 0, 4-300 (   7- 1 )
                         4-  4- 0, 4-307 (   7-10 )   4-  4- 0, 4-308 (   7-11 )

     114- G             NO COMPLEMENTARY AIRCRAFT CIRCUITS FOUND

     114- H             INTERFACE CONNECTION NOT USED BY TEST CASE STORE

     114- K             NO COMPLEMENTARY AIRCRAFT CIRCUITS FOUND

     114- L             NO COMPLEMENTARY AIRCRAFT CIRCUITS FOUND

     114- N             NO COMPLEMENTARY AIRCRAFT CIRCUITS FOUND

     114- P             NO COMPLEMENTARY AIRCRAFT CIRCUITS FOUND

     114- U             NO COMPLEMENTARY AIRCRAFT CIRCUITS FOUND

     114- X             NO COMPLEMENTARY AIRCRAFT CIRCUITS FOUND

     114- Y             NO COMPLEMENTARY AIRCRAFT CIRCUITS FOUND

     114- Z             NO COMPLEMENTARY AIRCRAFT CIRCUITS FOUND

     114- A*             4-  5- 0, 4-200 (927- G )    4-  5- 0, 4-201 (927- C )
                         4-  5- 0, 4-202 (927- R )    4-  5- 0, 4-203 (927- B*)
                         4-  5- 0, 4-216 (927- P )    4-  4- 0, 4-300 (   7- 1 )
                         4-  4- 0, 4-307 (   7-10 )   4-  4- 0, 4-308 (   7-11 )

     114- B*            NO COMPLEMENTARY AIRCRAFT CIRCUITS FOUND

     114- C*            NO COMPLEMENTARY AIRCRAFT CIRCUITS FOUND

     114- G*            NO COMPLEMENTARY AIRCRAFT CIRCUITS FOUND

     114- H*             4-  5- 0, 4-201 (927- C )    4-  5- 0, 4-202 (927- R )
                         4-  5- 0, 4-203 (927- B*)    4-  5- 0, 4-216 (927- P )

     114- N*            NO COMPLEMENTARY AIRCRAFT CIRCUITS FOUND
```

Figure 11 Sample Output for the Complementary Station Interface Circuit Analysis Program

COMPLEMENTARY STATION INTERFACE CIRCUIT ANALYSIS REPORT

STATION NO. 4 OF AIRCRAFT F-111A PAGE 2
CIRCUIT CHAR. SORTING MODE - COMPOSITE - WIRNG CATEG S.F.
TEST CASE STORE LAU-88A

TEST CASE STORE CONNECTOR IDENT AND PIN REF.	COMPLEMENTARY AIRCRAFT CIRCUITS (EQ. GRP. NO. & A/C CKT FN NO. & CONN.IDENT & PIN REF)
114- P*	NO COMPLEMENTARY AIRCRAFT CIRCUITS FOUND
114- R*	NO COMPLEMENTARY AIRCRAFT CIRCUITS FOUND
114- D*	INTERFACE CONNECTION NOT USED BY TEST CASE STORE
114- U*	INTERFACE CONNECTION NOT USED BY TEST CASE STORE
114- V*	NO COMPLEMENTARY AIRCRAFT CIRCUITS FOUND
114- W*	NO COMPLEMENTARY AIRCRAFT CIRCUITS FOUND
114- X*	NO COMPLEMENTARY AIRCRAFT CIRCUITS FOUND
114- Y*	NO COMPLEMENTARY AIRCRAFT CIRCUITS FOUND
114-AA	4- 5- 0, 4-217N(927- F) 4- 5- 0, 4-218N(927- E) 4- 4- 0, 4-305N(7- 7)
114- A	INTERFACE CONNECTION NOT USED BY TEST CASE STORE
114- E	INTERFACE CONNECTION NOT USED BY TEST CASE STORE
114- J	INTERFACE CONNECTION NOT USED BY TEST CASE STORE
114- M	INTERFACE CONNECTION NOT USED BY TEST CASE STORE
114- R	INTERFACE CONNECTION NOT USED BY TEST CASE STORE
114- S	INTERFACE CONNECTION NOT USED BY TEST CASE STORE
114- T	INTERFACE CONNECTION NOT USED BY TEST CASE STORE
114- V	INTERFACE CONNECTION NOT USED BY TEST CASE STORE
114- W	INTERFACE CONNECTION NOT USED BY TEST CASE STORE
114- D*	INTERFACE CONNECTION NOT USED BY TEST CASE STORE
114- E*	INTERFACE CONNECTION NOT USED BY TEST CASE STORE
114- F*	INTERFACE CONNECTION NOT USED BY TEST CASE STORE
114- K*	INTERFACE CONNECTION NOT USED BY TEST CASE STORE
114- H*	INTERFACE CONNECTION NOT USED BY TEST CASE STORE

Figure 11 Continued

COMPLEMENTARY STATION INTERFACE CIRCUIT ANALYSIS REPORT

STATION NO. 4 OF AIRCRAFT F-111A PAGE 3
CIRCUIT CHAR. SORTING MODE - COMPOSITE - WIRNG CATEG S.F.
TEST CASE STORE LAU-88A

TEST CASE STORE CONNECTOR IDENT AND PIN REF.	COMPLEMENTARY AIRCRAFT CIRCUITS (EQ.GRP. NO. & A/C CKT FN NO. & CONN.IDENT & PIN REF)
114- S*	INTERFACE CONNECTION NOT USED BY TEST CASE STORE
114- T*	INTERFACE CONNECTION NOT USED BY TEST CASE STORE
114- Z*	INTERFACE CONNECTION NOT USED BY TEST CASE STORE

Figure 11 Continued

AIRCRAFT STATION DATA RETRIEVAL PROGRAM. This computer program is designed to retrieve any part of, or all the interface data documented on the formats listed in Table I. The general arrangement of the Aircraft Station Data Retrieval Program is depicted in Figure 12.

A computer control (input) card deck is used in conjunction with the new aircraft interface data file to provide the following program control features.

a. Select applicable aircraft station.

b. Select data block printouts for station interface connector and/or station interface circuit wiring data.

c. Select data printouts for any one, a combination, or all aircraft interface connections peculiar to a specific store type.

d. Select electrical characteristic data block printouts (any one, a combination, or all) for those selected aircraft interface connections.

The Aircraft Station Data Retrieval Program summarizes all characteristics for each connector or circuit for each requested data section at the requested aircraft station.

a. The output is headed by a page of printout which summarizes all user-input definitions of data sections to be reported.

b. If the aircraft station connector data section is reqested for reporting, each connector characteristic of each connector of the given station is reported.

c. If the aircraft station wiring data section is requested for reporting, each wiring data characteristic for each electrical circuit at the given station is reported.

d. For each signal form data section (for a given equipment interface group) which is requested for reporting, each signal form data characteristic for each electrical circuit within the given equipment interface group is reported.

e. For each logic data section (for a given equipment interface group) which is requested for reporting, each logic data characteristic for each electrical circuit within the given equipment interface group is reported.

f. For each switching form/time data section (for a given equipment interface group) which is requested for reporting, each

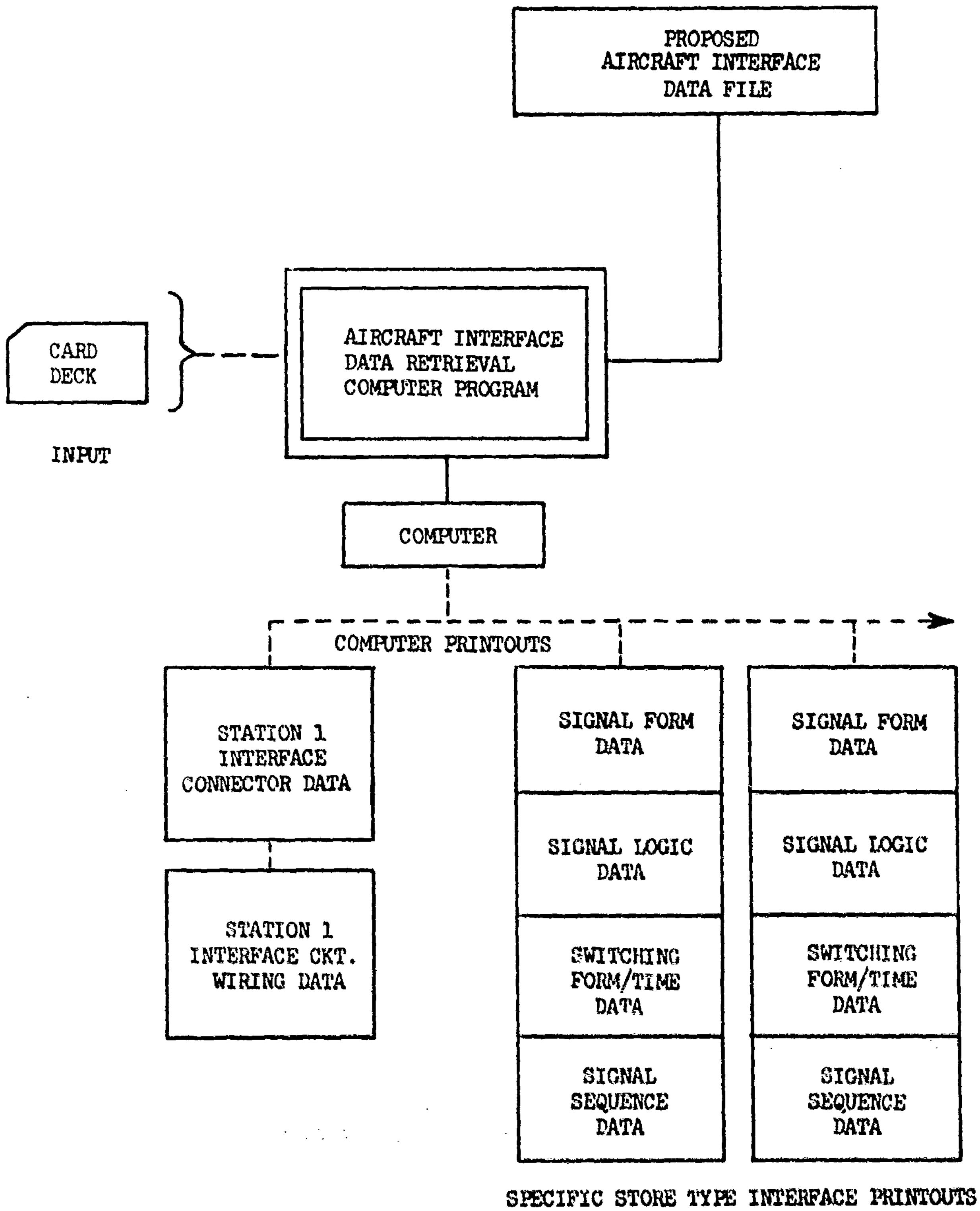

Figure 12. Aircraft Interface Data Retrieval Computer Program

switching form/time data characteristic for each electrical circuit within the given equipment interface group is reported.

g. For each sequence data section (for a given equipment interface group) which is requested for reporting, each sequence data characteristic for each electrical circuit within the given equipment interface group is reported.

Off-state or on-state matrix entries are shown as: A/C connector identification number; dash; A/C circuit pin letter; asterisk if pin lower case (else blank); equal sign; A/C sequence requirement (A = active, I = inactive, 0 = optional); semi-colon, as in:

102-A * = A; or

106-BB = I;

Sample printed output for this computer program is shown in Figure 13.

REVISED EQUIPMENT DATA RETRIEVAL PROGRAM. The existing Phase I Equipment Data Retrieval Program was revised to facilitate the retrieval and printout of all new store electrical characteristic data.

The method used to select store data for printout is described in AFATL-TR-73-214 Phase I. This procedure, however, was modified to permit retrieval of data associated with the new Switching Form/Time and Signal Sequence data blocks.

Additional computer printouts are provided for the supplemental and new equipment characteristic data blocks. The format of these printouts are essentially the same as the existing data block printouts (Figure 14).

```
AF305  AIRCRAFT STATION DATA RETRIEVAL PROGRAM
       SUMMARY OF USER-INPUT DATA OPTIONS
       ----------------------------------
       AIRCRAFT SELECTED  F-111E
       STATION SELECTED     4
       STATION DATA SECTIONS SELECTED --
           CONNECTOR      YES
           WIRING         YES

       ALL EQUIPMENT GROUPS REQUESTED

       EQUIPMENT GROUP DATA SECTIONS REQUESTED
           SIGNAL FORM       YES
           LOGIC             YES
           SWITCHING F/T     YES
           SEQUENCE          YES
```

Figure 13 Sample Output for the Aircraft Data Retrieval Program

AIRCRAFT F-111E STATION NO. 4 CONNECTOR DATA PAGE 1

A/C STN NO.	CONNCTR ID CODE NUMBER	CONNECTOR PART NUMBER	CONNCTR MARKER NUMBER	CONNCTR INSERT COMPAT. CODE NO	CONNECTOR INTERFACE FUNCTION	CONNECTOR PIN UTILIZATION: ACTIVE CKTS.	CONNECTOR PIN UTILIZATION: PIN ISOLN CKTS.	CONNECTOR PIN UTILIZATION: USABLE SPARE CKTS.	EQUIPMENT INTERFACE GROUP NO.: STN REF	EQUIPMENT INTERFACE GROUP NO.: STR GRP	EQUIPMENT INTERFACE GROUP NO.: S.O. GRP	CONTIN.
4	7	DMXXXX-19[illegible]	J469-1	Y 10	STORE	10	-0	2	4	4	-0	NO
4	927	LJTP00025-[illegible]		0560	STO FF	21	-0	8	4	5	-0	NO

Figure 13 Continued

AIRCRAFT F-111F STATION NO. 4 WIRING DATA (SECTION 1) PAGE 1

A/C CIRCUIT FUNCTION NO. STN REF	CKT	BRCH	GRD	NO CKT	AIRCRAFT CKT FUNCTION NOMENCLATURE	SIGNAL CATEGORY	AIRCRAFT/EQUIPMENT INTERFACE CONNECTION: CONN ID. CODE NO.	---CONNECTION--- PIN LTR	PIN L/C	PIN SIZE CODE	TERM NO.	MULTI-CONDCTR CABLE	WIRE TYPE	WIRE TYPE CODE
4	100			NO	MAN FIRE NO? RT	POWER	A	R	NO	N		A	SHIELDED	A
4	101	A		NO	STP JETT NO2	RELEASE	A	A	NO	N		A	SHIELDED	A
4	101	B		NO	OPR FIRE NO2	RELEASE	A	A	NO	N		A	SHIELDED	A
4	102			NO	MAN FIRE NO1 OT	POWER	A	B	NO	N		B	SHIELDED	A
4	103	A		NO	STP JETT NO1	RELEASE	A	C	NO	N		B	SHIELDED	A
4	103	B		NO	OPR FIRE NO1	RELEASE	A	C	NO	N		B	SHIELDED	A
4	104			NO	STR RIGHT ?	MONITOR	A	K	NO	N			STANDARD	A
4	104			NO	STR LEFT ?	MONITOR	A	U	NO	N			STANDARD	A
4	105		N	NO	STR RIGHT ? GRD	POWER	A	T	NO	N			STANDARD	A
4	105		N	NO	STR LEFT ? GRD	POWER	A	W	NO	N			STANDARD	A
4	106			NO	TAIL ARMING	CONTROL	A	K	YES	N			STANDARD	A
4	107			NO	NOSE/CTR ARMING	CONTROL	A	P	YES	N			STANDARD	A
4	108		N	NO	TAIL ARM RT	POWER	A	S	YES	N			STANDARD	A
4	109		N	NO	NOSE/CTR ARM RT	POWER	A	R	YES	N			STANDARD	A
4	110		N	NO	GROUND	POWER	A	J	YES	N			STANDARD	A
4	111			NO	UNK TCK [illegible] PWR	POWER	A	Z	NO	N			STANDARD	A
4	112			NO	UNK TCK IND	MONITOR	A	G	NO	N			STANDARD	A
4	113			NO	[illegible] RDY IND PWR	POWER	A	J	NO	N			STANDARD	A
4	114			NO	[illegible] RDY IND	MONITOR	A	K	NO	N			STANDARD	A
4	115			NO	IF S&P LOCK PWR	CONTROL	A	L	NO	N			STANDARD	A
4	116		N	NO	IF S&P LOCK GRD	POWER	A	M	NO	N			STANDARD	A
	-0			YES	JUMPED TO CKT R		A	C	YES	N				
	-0			YES	JUMPED TO CKT C		A	R	YES	N				
	-0			YES	NO CKT		A	F	NO	N				
	-0			YES	NO CKT		A	F	NO	N				
	-0			YES	NO CKT		A	G	NO	N				
	-0			YES	NO CKT		A	H	NO	N				
	-0			YES	NO CKT		A	N	NO	N				
	-0			YES	NO CKT		A	P	NO	N				
	-0			YES	NO CKT		A	S	NO	N				
	-0			YES	NO CKT		A	V	NO	N				
	-0			YES	NO CKT		A	A	YES	N				
	-0			YES	NO CKT		A	D	YES	N				
	-0			YES	NO CKT		A	F	YES	N				
	-0			YES	NO CKT		A	F	YES	N				
	-0			YES	NO CKT		A	G	YES	N				
	-0			YES	NO CKT		A	J	YES	N				
	-0			YES	NO CKT		A	H	YES	N				
	-0			YES	NO CKT		A	N	YES	N				
4	200			NO	[illegible] MONITOR	MONITOR	927	G	NO	N			STANDARD	A
4	201			NO	SAFE MONITOR	MONITOR	927	C	NO	N			STANDARD	A
4	202			NO	[illegible] RDY LOGIC	MONITOR	927	Q	NO	N			STANDARD	A
4	203			NO	SAFE PWR INTLK	MONITOR	927	D	YES	N			STANDARD	A
4	204	A		NO	SAFE PWR-NOR	CONTROL	927	A	NO	N			STANDARD	A
4	204	B		NO	SAFE PWR-SAFE	CONTROL	927	A	NO	N			STANDARD	A
4	204	C		NO	SAFE PWR-ARM	CONTROL	927	A	NO	N			STANDARD	A
4	[illegible]			NO	FAST DPLY V	SENSOR	927	V	NO	N			STANDARD	A
4	[illegible]			NO	FAST DPLY W	SENSOR	927	W	NO	N			STANDARD	A
4	205			NO	ARM POWER	CONTROL	927	H	NO	N			STANDARD	A
4	206			NO	ARM POWER	CONTROL	927	J	NO	N			STANDARD	A

Figure 13 Continued

AIRCRAFT F-111F STATION NO. 6 WIRING DATA (SECTION 2) PAGE 2

A/C CIRCUIT FUNCTION NO.				A/C INTERFACE CIRCUIT SOURCE					ADAPTER CABLE JUNCTION						
						CONNECTION									
STN REF	CKT	ARCH	GRD	EQUIP. ID CODE NUMBER	CONNECTOR ID CODE NUMBER	PIN LTR	PIN L/C	TERM NO.	CONNECTOR ID CODE NUMBER	PIN LTR	PIN L/C	ACFT CIRCUIT SOURCE	FLOATING SHIELD CIRCUIT	AIRCRAFT STRUCTURE GROUND	WIRE SIZE
6	100			6	971	A	NO		-0		NO	RETURN	NO	NO	[illegible]
6	[illegible]	A		6	971	39	NO		-0		NO	POWER	NO	NO	[illegible]
6	[illegible]	A		6	971	39	NO		-0		NO	POWER	NO	NO	[illegible]
6	[illegible]			6	971	14	NO		-0		NO	RETURN	NO	NO	[illegible]
6	[illegible]	A		6	971	46	NO		-0		NO	POWER	NO	NO	[illegible]
6	[illegible]	A		6	971	46	NO		-0		NO	POWER	NO	NO	[illegible]
6	[illegible]			6	912	37	NO		-0		NO	POWER	NO	NO	[illegible]
6	[illegible]			6	912	37	NO		-0		NO	POWER	NO	NO	[illegible]
6	[illegible]		N	994	-0		NO		-0		NO	RETURN	NO	NO	[illegible]
6	[illegible]		N	994	-0		NO		-0		NO	RETURN	NO	NO	[illegible]
6	[illegible]			6	971	17	NO		-0		NO	POWER	NO	NO	[illegible]
6	[illegible]			6	971	3	NO		-0		NO	POWER	NO	NO	[illegible]
6	[illegible]		N	994	-0		NO		-0		NO	RETURN	NO	NO	[illegible]
6	[illegible]		N	994	-0		NO		-0		NO	RETURN	NO	NO	[illegible]
6	[illegible]		N	994	-0		NO		-0		NO	RETURN	NO	YES	[illegible]
6	[illegible]			6	977	15	NO		-0		NO	POWER	NO	NO	[illegible]
6	[illegible]			6	977	16	NO		-0		NO	RETURN	NO	NO	[illegible]
6	[illegible]			6	977	23	NO		-0		NO	POWER	NO	NO	[illegible]
6	[illegible]			6	916	40	NO		-0		NO	RETURN	NO	NO	[illegible]
6	[illegible]			6	913	21	NO		-0		NO	POWER	NO	NO	[illegible]
6	[illegible]		N	994	-0		NO		-0		NO	RETURN	NO	NO	[illegible]
	-0			-0	-0		NO		-0		NO		NO	NO	-0
	-0			-0	-0		NO		-0		NO		NO	NO	-0
	-0			-0	-0		NO		-0		NO		NO	NO	-0
	-0			-0	-0		NO		-0		NO		NO	NO	-0
	-0			-0	-0		NO		-0		NO		NO	NO	-0
	-0			-0	-0		NO		-0		NO		NO	NO	-0
	-0			-0	-0		NO		-0		NO		NO	NO	-0
	-0			-0	-0		NO		-0		NO		NO	NO	-0
	-0			-0	-0		NO		-0		NO		NO	NO	-0
	-0			-0	-0		NO		-0		NO		NO	NO	-0
	-0			-0	-0		NO		-0		NO		NO	NO	-0
	-0			-0	-0		NO		-0		NO		NO	NO	-0
	-0			-0	-0		NO		-0		NO		NO	NO	-0
	-0			-0	-0		NO		-0		NO		NO	NO	-0
	-0			-0	-0		NO		-0		NO		NO	NO	-0
	-0			-0	-0		NO		-0		NO		NO	NO	-0
	-0			-0	-0		NO		-0		NO		NO	NO	-0
	-0			-0	-0		NO		-0		NO		NO	NO	-0
6	[illegible]			6	977	C	NO		-0		NO	POWER	NO	NO	20
6	[illegible]			6	977	C	NO		-0		NO	POWER	NO	NO	20
6	[illegible]			6	977	D	NO		-0		NO	POWER	NO	NO	20
6	[illegible]			6	977	B	YES		-0		NO	POWER	NO	NO	20
6	[illegible]	A		6	977	A	NO		-0		NO	POWER	NO	NO	16
6	[illegible]	B		6	977	A	NO		-0		NO	POWER	NO	NO	16
6	[illegible]	C		6	977	A	NO		-0		NO	POWER	NO	NO	16
6	[illegible]			6	977	W	NO		-0		NO	POWER	NO	NO	16
6	[illegible]			6	977	V	NO		-0		NO	RETURN	NO	NO	16
6	[illegible]			6	977	H	NO		-0		NO	POWER	NO	NO	16
6	206			6	977	J	NO		-0		NO	POWER	NO	NO	16

Figure 17 Continued

AIRCRAFT/EQUIPMENT INTERFACE CONNECTION

A/C CIRCUIT FUNCTION NO. SYM REF	CKT	BRCH	GRD	NO CKT	AIRCRAFT CKT FUNCTION NOMENCLATURE	SIGNAL CATEGORY	CONN ID. CODE NO.	CONNECTION PIN LTR	PIN L/C	PIN SIZE CODE	TERM NO.	MULTI-CONDCTR CABLE	WIRE TYPE	WIRE TYPE CODE
4	207			NO	OPT ARM SETLON	CONTROL	927	S	NO	N			STANDARD	A
4	208			NO	GROUND OPTS SEL	CONTROL	927	F	YES	N			STANDARD	A
4	209			NO	AIR OPTS SEL	CONTROL	927	Z	NO	N			STANDARD	A
4	210			NO	RETARD OPTS SEL	CONTROL	927	X	NO	N			STANDARD	A
4	211			NO	F/FALL OPTS SEL	CONTROL	927	D	YES	N			STANDARD	A
4	212			NO	IA OPTION	CONTROL	927	E	YES	N			STANDARD	A
4	213			NO	IR OPTION	CONTROL	927	Y	NO	N			STANDARD	A
4	214			NO	PAL GATE POWER	SENSOR	927	L	NO	N			STANDARD	A
4	215			NO	PAL CODE POWER	SENSOR	927	N	NO	N			STANDARD	A
4	216			NO	PAL UNLOCK	MONITOR	927	P	NO	N			STANDARD	A
4	217		N	NO	GROUND	POWER	927	F	NO	N			STANDARD	A
4	218		N	NO	GROUND	POWER	927	E	NO	N			STANDARD	A
4	-0			YES	NO CKT		927	A	YES	N				
4	-0			YES	NO CKT		927	C	YES	N				
4	-0			YES	NO CKT		927	K	NO	N				
4	-0			YES	NO CKT		927	M	NO	N				
4	-0			YES	NO CKT		927	G	NO	N				
4	-0			YES	NO CKT		927	R	NO	N				
4	-0			YES	NO CKT		927	U	NO	N				
4	-0			YES	NO CKT		927	T	NO	N				
4	300			NO	STORE IDENT 1	MONITOR	7	1	NO				STANDARD	A
4	301			NO	MODE ARM SEL	CONTROL	7	2	NO				STANDARD	A
4	302			NO	TAIL ARM SEL	CONTROL	7	3	NO				STANDARD	A
4	303			NO	PARK CONT ENR	POWER	7	4	NO				STANDARD	A
4	304			NO	OPT 3-DSP SEL	CONTROL	7	6	NO				STANDARD	A
4	305		N	NO	GROUND	POWER	7	7	NO				STANDARD	A
4	306	1		NO	SINGLE FIRE	RELEASE	7	8	NO				SHIELDED	A
4	306	8		NO	STORE JETTISON	RELEASE	7	R	NO				SHIELDED	A
4	307			NO	STORE IDENT 3	MONITOR	7	10	NO				STANDARD	A
4	308			NO	STORE IDENT 4	MONITOR	7	11	NO				STANDARD	A
4	-0			YES	NO CKT		7	5	NO					
4	309			NO	ARM PWR INTRLOK	CONTROL	7	9	NO				STANDARD	A
4	-0			YES	NO CKT		7	12	NO					
4	400			NO	OPT9 A/A LAUNCH	RELEASE	3	A	NO	N			SHIELDED	A
4	401			NO	OPT7 MASTER ARM	CONTROL	3	C	NO	N			STANDARD	A
4	402			NO	OPT5 DC STANDBY	POWER	3	B	NO	N			STANDARD	A
4	403			NO	OPT5 115VAC PWR	POWER	3	J	NO	N			STANDARD	A
4	404			NO	JETTISON	RELEASE	3	L	NO	N			SHIELDED	A
4	405			NO	A/A TONE IN	SENSOR	3	K	NO	N			SHIELDED	A
4	406		N	NO	GROUND	POWER	3	E	NO	N			STANDARD	A
4	407			NO	STORE IDENT 1	MONITOR	3	I	NO	N			STANDARD	A
4	408			NO	STORE IDENT 3	MONITOR	3	I	NO	N			STANDARD	A
4	409			NO	OPT M-16 SELECT	CONTROL	3	F	NO	N			STANDARD	A
	-0			YES	NO CKT		3	D	NO	N				
	-0			YES	NO CKT		3	G	NO	N				
	-0			YES	NO CKT		3	H	NO	N				
	-0			YES	NO CKT		3	K	NO	N				
	-0			YES	NO CKT		3	N	NO	N				
4	600			NO	BOMB RELEASE	RELEASE	6	8	NO					
4	601		N	NO	GROUND	POWER	6	7	NO					

Figure 13 Continued

AIRCRAFT F-111E   STATION NO. 4   WIRING DATA (SECTION 2)   PAGE 4

A/C CIRCUIT FUNCTION NO.				A/C INTERFACE CIRCUIT SOURCE		CONNECTION			ADAPTER CABLE JUNCTION						
STN REF	CKT	ARCH	GRD	EQUIP. ID CODE NUMBER	CONNECTR ID CODE NUMBER	PIN LTR	PIN L/C	TERM NO.	CONNECTR ID CODE NUMBER	PIN LTR	PIN L/C	ACFT CIRCUIT SOURCE	FLOATING SHIELD CIRCUIT	AIRCRAFT STRUCTURE GROUND	WIRE SIZE
4	207			6	927	S	NO		-0		NO	RETURN	NO	NO	16
4	208			6	927	F	YES		-0		NO	POWER	NO	NO	16
4	209			6	927	Z	NO		-0		NO	POWER	NO	NO	16
4	210			6	927	X	NO		-0		NO	POWER	NO	NO	16
4	211			6	927	D	YES		-0		NO	POWER	NO	NO	16
4	212			6	927	E	YES		-0		NO	POWER	NO	NO	16
4	213			6	927	Y	NO		-0		NO	POWER	NO	NO	16
4	214			9	932	D	YES		-0		NO	POWER	NO	NO	20
4	215			9	932	X	NO		-0		NO	POWER	NO	NC	20
4	216			10	933	S	YES		-0		NO	POWER	NO	NO	20
4	217		N	6	927	F	NO		-0		NO	RETURN	NO	YES	16
4	218		N	6	927	E	NO		-0		NO	RETURN	NO	YES	16
4	-0			-0	-0		NO		-0		NO		NO	NO	-0
4	-0			-0	-0		NO		-0		NO		NO	NO	-0
4	-0			-0	-0		NO		-0		NO		NO	NO	-0
4	-0			-0	-0		NO		-0		NO		NO	NO	-0
4	-0			-0	-0		NO		-0		NO		NO	NO	-0
4	-0			-0	-0		NO		-0		NO		NO	NO	-0
4	-0			-0	-0		NO		-0		NO		NO	NO	-0
4	-0			-0	-0		NO		-0		NO		NO	NO	-0
4	300			2	916	36	NO		950	24	NO	POWER	NO	NO	20
4	301			4	923	35	NO		950	7	NO	POWER	NO	NO	20
4	302			4	923	11	NO		950	L	NO	POWER	NO	NO	20
4	303			7	-0		NO		950	35	NO	POWER	NO	NO	18
4	304			4	923	25	NO		950	36	NO	POWER	NO	NO	18
4	305		N	999	-0		NO		950	22	NO	RETURN	NO	YES	18
4	306	A		4	923	1	NO		950	38	NO	POWER	NO	NO	18
4	306	B		4	923	1	NO		950	38	NO	POWER	NO	NO	18
4	307			2	912	33	NC		950	26	NO	POWER	NO	NO	20
4	308			2	912	39	NO		950	23	NO	POWER	NO	NO	20
4	-0			-0	-0		NO		-0		NO		NO	NO	-0
4	309			4	923	54	NO		950	21	NC	RETURN	NO	NO	20
4	-0			-0	-0		NC		-0		NO		NO	NO	-0
4	400			4	923	34	NO		950	27	NO	POWER	NO	NO	20
4	401			4	923	44	NO		950	16	NO	POWER	NO	NO	20
4	402			4	924	38	NO		950	29	NO	POWER	NO	NO	16
4	403			4	924	27	NO		950	41	NO	POWER	NO	NO	20
4	404			4	923	40	NC		950	39	NO	POWER	NO	NO	20
4	405			2	912	35	NO		950	2	NO	RETURN	NO	NO	20
4	406		N	999	-0		NO		950	15	NO	RETURN	NO	YES	16
4	407			2	912	36	NO		950	24	NO	POWER	NO	NO	20
4	408			2	912	38	NC		950	26	NO	POWER	NO	NO	20
4	409			4	923	45	NO		950	.	NC	POWER	NO	NO	20
	-0			-0	-0		NO		-0		NO		NO	NO	-0
	-0			-0	-0		NO		-0		NO		NO	NO	-0
	-0			-0	-0		NO		-0		NO		NO	NO	-0
	-0			-0	-0		NO		-0		NO		NO	NO	-0
	-0			-0	-0		NO		-0		NO		NO	NO	-0
4	600			-0	-0		NO		-0		NO	POWER	NO	NO	-0
4	601		N	999	-0		NO		-0		NO	RETURN	NO	NO	-0

Figure 13 Continued

AIRCRAFT F-111F STATION NO. 4 WIRING DATA (SECTION 1) PAGE 5

A/C CIRCUIT FUNCTION NO. STN REF	CKT	BRCH	GRD	NO CKT	AIRCRAFT CKT FUNCTION NOMENCLATURE	SIGNAL CATEGORY	AIRCRAFT/EQUIPMENT INTERFACE CONNECTION: CONN ID. CODE NO.	CONNECTION: PIN LTR	PIN L/C	PIN SIZE CODE	TERM NO.	MULTI-CONDCTR CABLE	WIRE TYPE	WIRE TYPE CODE
4	602			NO	ROCKET FIRE	RELEASE	6	6	NO					
4	603		H	NO	GROUND	POWER	6	5	NO					
4	701		H	NO	TK SIM LOOP	POWER	1	A	NO				STANDARD	A
4	702			NO	RAYS TO SM1 H	SENSOR	1	B	NO				SHIELDED	A
4	703			NO	RAYS TO OT1 H	SENSOR	1	C	NO				SHIELDED	A
4	704			NO	RAYS TO OT2 L	SENSOR	1	D	NO				STANDARD	A
4	705			NO	TK SIM LOOP	MONITOR	1	E	NO				STANDARD	A
4	706			NO	RAYS TO SM2 H	SENSOR	1	F	NO				SHIELDED	A
4	707			NO	RAYS TO OT2 H	SENSOR	1	G	NO				SHIELDED	A
4	708			NO	RAYS TO OT1 L	SENSOR	1	H	NO				STANDARD	A
4	709		H	NO	LO LEVEL NO 1A	POWER	2	A	NO				STANDARD	A
4	710			NO	LO LEVEL CM 1A	MONITOR	2	B	NO				STANDARD	A
4	711		H	NO	GROUND S1	POWER	2	C	NO				STANDARD	A
4	712			NO	LO LEVEL NO 1B	POWER	2	D	NO				STANDARD	A
4	713			NO	LO LEVEL CM 1B	MONITOR	2	E	NO				STANDARD	A
4	714			NO	HI LEVEL NO 2A	POWER	2	G	NO				STANDARD	A
4	715			NO	HI LEVEL CM 2A	MONITOR	2	H	NO				STANDARD	A
4	716		H	NO	GROUND S2	POWER	2	J	NO				STANDARD	A

Figure 13 Continued

AIRCRAFT F-111E STATION NO. 4 WIRING DATA (SECTION 2) PAGE 6

A/C CIRCUIT FUNCTION I.D.				A/C INTERFACE CIRCUIT SOURCE					ADAPTER CABLE JUNCTION						
						CONNECTION									
STN REF	CKT	BRCK	GRD	EQUIP. ID CODE NUMBER	CONNCTR ID CODE NUMBER	PIN LTR	PIN L/C	TERM NO.	CONNCTR ID CODE NUMBER	PIN LTR	PIN L/C	ACFT CIRCUIT SOURCE	FLOATING SHIELD CIRCUIT	AIRCRAFT STRUCTURE GROUND	WIRE SIZE
4	602			-0	-0		NO		-0		NO	POWER	NO	NO	-0
4	603		M	999	-0		NO		-0		NO	RETURN	NO	NO	-0
4	701		M	999	-0		NO		954	A	NO	RETURN	NO	NO	-0
4	702			-0	-0		NO		954	B	NO		NO	NO	-0
4	703			-0	-0		NO		954	C	NO		NO	NO	-0
4	704			-0	-0		NO		954	D	NO		NO	NO	-0
4	705			-0	-0		NO		954	E	NO	POWER	NO	NO	-0
4	706			-0	-0		NO		954	F	NO		NO	NO	-0
4	707			-0	-0		NO		954	G	NO		NO	NO	-0
4	708			-0	-0		NO		954	H	NO		NO	NO	-0
4	709		M	999	-0		NO		950	14	NO	RETURN	NO	NO	-0
4	710			-0	-0		NO		950	5	NO	POWER	NO	NO	-0
4	711		M	999	-0		NO		950	22	NO	RETURN	NO	YES	-0
4	712			-0	-0		NO		950	40	NO	RETURN	NO	NO	-0
4	713			-0	-0		NO		950	13	NO	POWER	NO	NO	-0
4	714			-0	-0		NO		950	4	NO	RETURN	NO	NO	-0
4	715			-0	-0		NO		950	3	NO	POWER	NO	NO	-0
4	716		M	999	-0		NO		950	15	NO	RETURN	NO	YES	-0

Figure 13 Continued

SIGNAL FORM DATA (SECTION 1)

AIRCRAFT F-111E   STATION NO. 4   EQUIPMENT GROUP 4- 0   PAGE 1

A/C CIRCUIT FUNCTION NO. STN REF	CKT	ARCH	GRD	ON STATE SOURCE	CIRCUIT TYPE CKT LOAD	CKT SWT	CURR. LIMTR	OFF STATE	MULTI WIRE STORE CONN.	CIRCUIT VOLTAGE SOURCE VALUE MIN. VOLTS	MAX. VOLTS	TYPE	MINIMUM INTERFACE VOLTAGE
4	300			POWER	YES	YES	NO	PARALLEL LOAD TO GRD		-0.000	-0.000		-0.000
4	301			POWER	NO	YES	NO	OPEN CIRCUIT		26.000	29.500	DC	25.000
4	302			POWER	NO	YES	NO	OPEN CIRCUIT		26.000	29.500	DC	25.000
4	303			POWER	NO	NO	NO	PARALLEL LOAD TO GRD		26.000	29.500	DC	25.000
4	304			POWER	NO	YES	NO	OPEN CIRCUIT		26.010	29.500	DC	25.000
4	305		H	RETURN	NO	NO	NO	GROUNDED		-0.000	-0.000		-0.000
4	306	1		POWER	NO	YES	NO	OPEN CIRCUIT		26.000	29.500	DC	25.000
4	306			POWER	NO	YES	NO	OPEN CIRCUIT		26.000	29.500	DC	25.000
4	307			POWER	YES	YES	NO	PARALLEL LOAD TO GRD		-0.000	-0.000		-0.000
4	308			POWER	YES	YES	NO	PARALLEL LOAD TO GRD		-0.000	-0.000		-0.000
4	-0				NO	NO	NO			-0.000	-0.000		-0.000
4	309			RETURN	YES	NO	NO	PARALLEL LOAD TO GRD		26.000	29.500	DC	27.000
4	-0				NO	NO	NO			-0.000	-0.000		-0.000

Figure 13 Continued

SIGNAL FORM DATA (SECTION 2)

AIRCRAFT F-111E STATION NO. 4 EQUIPMENT GROUP 4- 0 PAGE 2

A/C CIRCUIT FUNCTION NO.				A/C CIRCUIT BREAKER SOURCE		MAXIMUM CIRCUIT LOAD			LOAD LIMIT COMPON. ID CODE NUMBER	A/C WIRE RESIST.	SENSOR CIRCUIT SF/LOGIC CODE NO.	PARALLEL CIRCUIT STORE LOAD MULTIPLIC. FACTOR	SUMMATE PARALLEL CIRCUIT STORE LOAD
						STEADY STATE	TRANSIENT						
STN REF	CKT	BRCH	GRD	COMPON. ID CODE NUMBER	RATING (AMPS)	CURRENT (AMPS)	CURRENT (AMPS)	TIME (SECS)					
4	300			-0	-0	-0.000	-0.000	-0.00	-0	-0.000	-0	-0	
4	301			324	15	12.000	-0.000	-0.00	-0	-0.000	-0	-0	
4	302			324	15	10.000	-0.000	-0.00	-0	-0.000	-0	-0	
4	303			324	15	15.000	-0.000	-0.00	324	-0.000	-0	-0	
4	304			324	15	10.000	-0.000	-0.00	-0	-0.000	-0	-0	
4	305		M	-0	-0	-0.000	-0.000	-0.00	-0	-0.000	-0	-0	
4	306	A		312	15	15.000	-0.000	-0.00	-0	-0.000	-0	-0	
4	306	B		312	15	10.000	-0.000	-0.00	-0	-0.000	-0	-0	
4	307			-0	-0	-0.000	-0.000	-0.00	-0	-0.000	-0	-0	
4	308			-0	-0	-0.000	-0.000	-0.00	-0	-0.000	-0	-0	
4	-0			-0	-0	-0.000	-0.000	-0.00	-0	-0.000	-0	-0	
4	309			-0	-0	-0.000	-0.000	-0.00	-0	-0.000	-0	-0	
4	-0			-0	-0	-0.000	-0.000	-0.00	-0	-0.000	-0	-0	

Figure 13 Continued

LOGIC DATA (SECTION 3)

AIRCRAFT F-111F STATION NO. 4 EQUIPMENT GROUP 4- 0 PAGE 1

RELEASE

A/C CIRCUIT FUNCTION NO.				OPERATE FUNCTION						
STN REF	CKT	BRCH	GRD	PYLON JETTISON	BOMB RACK	LAUNCHER	STORE INTERFACE	MASTER ARM SWTCH	GRD SFTY	RELEASE INITIATE SWITCH
4	300			NONE CHKD	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	
4	301			NONE CHKD	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	
4	302			NONE CHKD	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	
4	303			NONE CHKD	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	
4	304			NONE CHKD	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	
4	305		M	NONE CHKD	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	
4	306	A		NONE CHKD	NONE CHECKED	NONE CHECKED	STORE FIRING ONLY	YES	YES	BOMB/ROCKET BUTTON
4	306	B		NONE CHKD	NONE CHECKED	NONE CHECKED	SUP RACK EJECT/JETT.	YES	YES	BOMB/ROCKET BUTTON
4	307			NONE CHKD	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	
4	308			NONE CHKD	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	
4	-3			NONE CHKD	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	
4	309			NONE CHKD	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	
4	-0			NONE CHKD	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	

Figure 13 Continued

LOGIC DATA (SECTION 2)

AIRCRAFT F-111E STATION NO. 4 EQUIPMENT GROUP 4- 0

A/C CIRCUIT FUNCTION NO.				MONITOR									CONTROL	
					-- MONITOR OP FN --									
STN REF	CKT	BRCH	GRD	OPES STAT	DISP STOR PRES	STR IN.	CKT SMT LCK	STR QTY	CKT MONITR POINT	STATN. MONITR POINT	OP STAT DISPLAY CODE NO	SPARE DISPLAY AVAIL.	INFLIGHT SELECTION	CONTROL LOGIC
4	300			NO	NO	YES	NO	NO	STORE	NO	-0	NO	DIRECT OPTN.	MULT. BRK
4	301			NO	NO	NO	NO	NO		NO	-0	NO	DIRECT OPTN.	MULT. BRK
4	302			NO	NO	NO	NO	NO		NO	-0	NO		
4	303			NO	NO	NO	NO	NO		NO	-0	NO	DIRECT OPTN.	SINGLE BRK
4	304			NO	NO	NO	NO	NO		NO	-0	NO		
4	305		M	NO	NO	NO	NO	NO		NO	-0	NO		
4	[illegible]	A		NO	NO	NO	NO	NO		NO	-0	NO		
4	306	B		NO	NO	NO	NO	NO		NO	-0	NO		
4	307			NO	NO	NO	YES	NO	STORE	NO	-0	NO		
4	308			NO	NO	NO	YES	NO	STORE	NO	-0	NO		
4	-0			NO	NO	NO	NO	NO		NO	-0	NO	AUTO CONTROL	
4	309			NO	NO	NO	NO	NO		NO	-0	NO		
4	-0			NO	NO	NO	NO	NO		NO	-0	NO		

Figure 13 Continued

LOGIC DATA (SECTION 3)

AIRCRAFT F-111E

STATION NO. 4 EQUIPMENT GROUP 4- 0

A/C CIRCUIT FUNCTION NO.				POWER	SENSOR	GENERAL			
STN REF	CKT	ARCH	GRD	POWER SIGNAL LOGIC	SENSOR CKT SF/LOGIC CODE NO.	STATION ISOLATE	UNIQUE	STATION SELECT	CONTROL CKT. LOGIC OPERATE FN CODE NO.
4	300				-0	YES	NO	NO	-0
4	301				-0	YES	NO	YES	-0
4	302				-0	YES	NO	YES	-0
4	303			PWR SOURCE	-0	YES	NO	NO	-0
4	304				-0	NO	NO	NO	-0
4	305		W	PWR RETURN	-0	NO	NO	NO	-0
4	306	A			-0	YES	NO	YES	-0
4	306	B			-0	YES	NO	YES	-0
4	307				-0	YES	NO	NO	-0
4	308				-0	YES	NO	NO	-0
4	-0				-0	NO	NO	NO	-0
4	304				-0	YES	NO	NO	-0
4	-0				-0	NO	NO	NO	-0

Figure 13 Continued

SWITCHING FORM/TIME DATA (SECTION 1)

AIRCRAFT F-111P STATION NO. 4 EQUIPMENT GROUP 4- 0 PAGE 1

CIRCUIT SWITCHING FORM

A/C CIRCUIT FUNCTION NO.						A/C INPUT CIRCUIT REQUIREMENTS					
STN REF	CKT	BRCH	GRD	INPUT/OUTPUT	A/C OUTPUT CKT. FORM	MAINT	MOMEN.	PULSC	NON-SWTCHD	OPTNL	A/C OUTPUT CKT COMPONENT IC CODE NO.
4	100			A/C OUTPUT CIRCUIT	MAINTAINED	NO	NO	NO	NO	NO	-0
4	101			A/C OUTPUT CIRCUIT	MAINTAINED	NO	NO	NO	NO	NO	-0
4	102			A/C OUTPUT CIRCUIT	MAINTAINED	NO	NO	NO	NO	NO	-0
4	103			A/C OUTPUT CIRCUIT	NON SWITCHED	NO	NO	NO	NO	NO	-0
4	104			A/C OUTPUT CIRCUIT	MAINTAINED	NO	NO	NO	NO	NO	-0
4	105		B	A/C INPUT CIRCUIT	NONE CHECKED	NO	NO	NO	YES	NO	-0
4	106	A		A/C OUTPUT CIRCUIT	PULSED	NO	NO	NO	NO	NO	-0
4	106	B		A/C OUTPUT CIRCUIT	PULSED	NO	NO	NO	NO	NO	-0
4	107			A/C OUTPUT CIRCUIT	MAINTAINED	NO	NO	NO	NO	NO	-0
4	108			A/C OUTPUT CIRCUIT	MAINTAINED	NO	NO	NO	NO	NO	-0
4	-0				NONE CHECKED	NO	NO	NO	NO	NO	-0
4	109			A/C INPUT CIRCUIT	NONE CHECKED	NO	NO	NO	NO	YES	-0
4	-0				NONE CHECKED	NO	NO	NO	NO	NO	-0

Figure 13 Continued

SWITCHING FORM/TIME DATA (SECTION 2)

AIRCRAFT F-111F   STATION NO. 4   EQUIPMENT GROUP 4- 0   PAGE 2

A/C CIRCUIT FUNCTION NO.				CIRCUIT SWITCHING TIME													
				CKT INITIATE DELAY TIME			CIRCUIT ON TIME				CKT DROPOUT DELAY TIME			CKT (OFF) DWELL TIME			
STN REF	CKT	BRCH	GRD	VAR SET	MIN. (SEC)	MAX. (SEC)	VAR SET	MIN. (SEC)	MAX. (SEC)	INDEF	VAR SET	MIN. (SEC)	MAX. (SEC)	VAR SET	MIN. (SEC)	MAX. (SEC)
4	300			NO	-1.000	-0.300	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
4	301			NO	-3.100	-3.000	NO	-0.000	-0.000	YES	NO	2.000	2.000	NO	-0.000	-0.000
4	302			NO	-3.000	-0.000	NO	-0.000	-0.000	YES	NO	2.000	2.000	NO	-0.000	-0.000
4	303			NO	-0.000	-0.043	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
4	304			NO	-0.200	-0.100	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
4	305	A	H	NO	-0.000	-0.040	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
4	306	B		NO	-0.000	-0.040	YES	.010	9999.000	NO	NO	-0.000	-0.000	YES	.020	.666
4	306			NO	-0.400	-0.030	NO	.045	.055	NO	NO	-0.000	-0.000	NO	.030	.037
4	307			NO	-0.400	-0.100	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
4	308			NO	-3.200	-3.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
4	-0			NO	-0.000	-0.000	NO	-0.000	-0.100	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
4	309			NO	-0.000	-0.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
4	-0			NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000

Figure 13 Continued

AIRCRAFT F-111F

SEQUENCE DATA

STATION NO. 4   EQUIPMENT GROUP 4- 0   PAGE 1

A/C CIRCUIT FUNCTION NO.				AIRCRAFT INTERFACE CONNECT			INTERFACE CIRCUIT SIGNAL FUNCTION	STORE LOOP CIRCUIT ID		IF SIGNAL SW. SEQ. ORDER
STN REF	CKT	BRCH	GRD	CONN ID CODE NO	--PIN-- LTR	L/C		POWER	RETURN	
4	100			7	1		SUPPORT FN. SIGNAL	YES		1
4	[illegible]			7	2		PRIME FN. SIGNAL	YES		2
4	[illegible]			7	3		PRIME FN. SIGNAL	YES		2
4	[illegible]			7	3		SUPPORT FN. SIGNAL	YES		1
4	[illegible]			7	4		NO DATA			
4	[illegible]		N	7	5		PRIME FN. SIGNAL	YES		3
4	[illegible]	A		7	6		DIRECT PWR RET. CKT.		YES	1
4	[illegible]	B		7	7		PRIME FN. SIGNAL	YES		0
4	[illegible]			7	8		PRIME FN. SIGNAL	YES		0
4	[illegible]			7	8		SUPPORT FN. SIGNAL	YES		1
4	[illegible]			7	9		SUPPORT FN. SIGNAL	YES		1
4	[illegible]			7	11		SUPPORT FN. SIGNAL	YES		1
4	[illegible]			7	12		NO DATA			

Figure 13 Continued

AIRCRAFT F-111E

SEQUENCE DATA

STATION NO. 4 EQUIPMENT GROUP 4- 0

OFF STATE AIRCRAFT CIRCUIT DATA MATRIX

ASSOCIATED AIRCRAFT INTERFACE CIRCUITS

A/C CIRCUIT FUNCTION NO. STN REF	CKT	BRCH	GRD	ASSOCIATED AIRCRAFT INTERFACE CIRCUITS
4	300			NO ENTPIES
4	301			7- 1 =0; 7- 3 =0; 7- 4 =A; 7- 6 =0; 7- 7 =A; 7- 8 =0; 7- 8 =0; 7- 9 =0; 7-10 =0
4	302			7- 1 =0; 7- 2 =0; 7- 4 =A; 7- 6 =0; 7- 7 =A; 7- 8 =0; 7- 8 =0; 7- 9 =0; 7-10 =0
4	303			NC ENTRIFS
4	-0			NO ENTPIES
4	304			7- 1 =A; 7- 2 =0; 7- 3 =0; 7- 4 =A; 7- 7 =A; 7- 8 =0; 7- 8 =0; 7- 9 =0; 7-10 =0
4	305		N	NC ENTPIES
4	306	A		7- 1 =0; 7- 2 =0; 7- 3 =0; 7- 4 =A; 7- 6 =0; 7- 7 =A; 7- 8 =0; 7- 9 =0; 7-10 =0
4	306	B		7- 1 =0; 7- 2 =0; 7- 3 =0; 7- 4 =A; 7- 6 =0; 7- 7 =A; 7- 8 =0; 7- 9 =0; 7-10 =0
4	309			NO ENTPIES
4	307			NC ENTPIES
4	308			NC ENTPIES
4	-0			NC ENTPIES

Figure 13 Continued

AIRCRAFT F-111E

SEQUENCE DATA

STATION NO. 4 EQUIPMENT GROUP 4- 0 PAGE 3

ON STATE AIRCRAFT CIRCUIT DATA MATRIX

A/C CIRCUIT FUNCTION NO.

STN RES	CKT	BRCH	GRD	ASSOCIATED AIRCRAFT INTERFACE CIRCUITS
4	380			NO ENTRIES
4	381			7- 1 =A; 7- 3 =O; 7- 4 =A; 7- 6 =I; 7- 7 =A; 7- 8 =O; 7- 8 =A; 7- 9 =A; 7-10 =A
4	382			7- 1 =A; 7- 2 =O; 7- 4 =A; 7- 6 =I; 7- 7 =A; 7- 8 =O; 7- 8 =A; 7- 9 =A; 7-10 =A
4	383			NO ENTRIES
4	-8			NO ENTRIES
4	384			7- 1 =A; 7- 2 =I; 7- 3 =I; 7- 4 =A; 7- 7 =A; 7- 8 =O; 7- 8 =A; 7- 9 =A; 7-10 =A
4	385		N	NO ENTRIES
4	386	A		7- 1 =A; 7- 2 =O; 7- 3 =O; 7- 4 =A; 7- 6 =O; 7- 7 =A; 7- 8 =A; 7- 9 =A; 7-10 =A
4	386	B		7- 1 =A; 7- 2 =I; 7- 3 =I; 7- 4 =A; 7- 6 =I; 7- 7 =A; 7- 8 =A; 7- 9 =A; 7-10 =A
4	389			NO ENTRIES
4	387			NO ENTRIES
4	388			NO ENTRIES
4	-8			NO ENTRIES

END OF REPORT.

Figure 13 Continued

100127 INTRODUCTORY (CONNECTOR) DATA

STORE OR SUSP. DEV. NOMENCLAT.	STORE OR SUSP. DEV. IDENTIFIC.	SECURITY CLASSIF.	ELECTRICAL CONNECTOR TYPE NUMBER	CODE	NUMBER ACTIVE CKTS	NUMBER SPARE PINS	CONNECTOR INSERT COMPATIBL. CODE NO.	NUMBER OF CONN. PIN ISOLATION CIRCUITS
LIU 88A	10-01-27	UNCLASS.	LJT07RE-25-46PB	114	27	19	0585	3

TOTAL NUMBER OF CONNECTORS 1
TOTAL NUMBER ACTIVE & SPARE CIRCUITS 46
TOTAL NUMBER OF CONN. PIN ISOL. CKTS. 3

Figure 14 Sample Output for the Revised Equipment Data Retrieval Program

100127 ELECTRICAL SIGNAL FORM DATA PAGE 1

CKT NO.	CKT FUNCTION NOMENCLATURE	PIN REF. NO	PIN REF. L/C	PIN CODE	SIGNAL CATEGORY	WIRE TYPE	WIRE CODE
1	ADAPT EX POS	B	NO	D=20	SENSOR	STANDARD	A=STD-A
2	28VDC PWR	C	NO	D=20	POWER	STANDARD	A=STD-A
3	MANUAL SEQ	D	NO	D=20	CONTROL	STANDARD	A=STD-A
4	STARBOARD ID	F	NO	D=20	MONITOR	STANDARD	A=STD-A
5	STA SELECT	G	NO	D=20	CONTROL	STANDARD	A=STD-A
6	SPAR/LAU PPS	H	NO	D=20	SPARE	NO ENTRY	=
7	A7 COMMAND	K	NO	D=20	SENSOR	STANDARD	A=STD-A
8	FL COMMAND	L	NO	D=20	SENSOR	STANDARD	A=STD-A
9	F4 IDENT NC	N	NO	D=20	CONTROL	STANDARD	A=STD-A
10	DOME CVR PWR	P	NO	D=20	CONTROL	STANDARD	A=STD-A
11	FRAME GRD	U	NO	D=20	POWER	STANDARD	A=STD-A
12	F4 UNCAGE NC	X	NO	D=20	CONTROL	STANDARD	A=STD-A
13	ADAPT EX NEG	Y	NO	D=20	SENSOR	STANDARD	A=STD-A
14	TRACK MODE 3	Z	NO	D=20	SENSOR	STANDARD	A=STD-A
15	AGM65A ID	A	YES	D=20	MONITOR	STANDARD	A=STD-A
16	TRACK	B	YES	D=20	CONTROL	STANDARD	A=STD-A
17	AGM65A SEL	C	YES	D=20	CONTROL	STANDARD	A=STD-A
18	AC PWR RET	G	YES	D=20	POWER	STANDARD	A=STD-A
19	SEL MSL RDY	H	YES	D=20	MONITOR	STANDARD	A=STD-A
20	ANALOG RET	N	YES	D=20	POWER	STANDARD	A=STD-A
21	SINGL MS JET	P	YES	D=20	RELEASE	STANDARD	A=STD-A
22	LAUNCH	R	YES	D=20	RELEASE	STANDARD	A=STD-A
23	SPAR/OLD LAU	Q	YES	D=20	SPARE	NO ENTRY	=
24	A7 UNCAGE	U	YES	D=20	SPARE	NO ENTRY	A=
25	AC PWR PH A	V	YES	N=16	POWER	STANDARD	A=STD-A
26	COMP VIDEO	W	YES	M= 8	SENSOR	COAXIAL	A=RG-A
27	AC PWR PH B	X	YES	N=16	POWER	STANDARD	A=STD-A
28	AC PWR PH C	Y	YES	N=16	POWER	STANDARD	A=STD-A
29	28VDC GROUND	AA	NO	N=16	POWER	STANDARD	A=STD-A
30	TEST FUNCT	A	NO	D=20	SPARE	NO ENTRY	=
31	NO CKT	E	NO	D=20	SPARE	NO ENTRY	=
32	TEST FUNCT	J	NO	D=20	SPARE	NO ENTRY	=
33	TEST FUNCT	M	NO	D=20	SPARE	NO ENTRY	=
34	PIN ISOLATE	R	NO	D=20	SPARE	NO ENTRY	=
35	PIN ISOLATE	S	NO	D=20	SPARE	NO ENTRY	=
36	PIN ISOLATE	T	NO	D=20	SPARE	NO ENTRY	=
37	NO CKT	V	NO	D=20	SPARE	NO ENTRY	=
38	TEST FUNCT	W	NO	D=20	SPARE	NO ENTRY	=
39	NO CKT	D	YES	D=20	SPARE	NO ENTRY	=
40	TEST FUNCT	E	YES	D=20	SPARE	NO ENTRY	=
41	TEST FUNCT	F	YES	D=20	SPARE	NO ENTRY	=
42	NO CKT	K	YES	D=20	SPARE	NO ENTRY	=
43	NO CKT	M	YES	D=20	SPARE	NO ENTRY	=
44	TEST FUNCT	S	YES	D=20	SPARE	NO ENTRY	=
45	TEST FUNCT	T	YES	D=20	SPARE	NO ENTRY	=
46	NO CKT	Z	YES	M= 8	SPARE	NO ENTRY	=

Figure 14 Continued

100127 ELECTRICAL SIGNAL FORM DATA PAGE 2

CKT NO.	VOLTAGE VALUE	VOLT TYPE	STEADY AMPS	LOAD TYPE IND.	RES.	LAMP	MOTOR	GROUND CIRCUIT
1	-15.0000	DC	-0.0000	NO	NO	NO	NO	NO
2	28.0000	DC	5.0000	YES	YES	NO	NO	NO
3	28.0000	DC	.2500	YES	NO	NO	NO	NO
4	-0.0000	NONE	-0.0000	NO	NO	NO	NO	YES
5	28.0000	DC	.2500	YES	NO	NO	NO	NO
6	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO
7	15.0000	OTH	-0.0000	NO	NO	NO	NO	NO
8	15.0000	OTH	-0.0000	NO	NO	NO	NO	NO
9	28.0000	DC	.2500	YES	NO	NO	NO	NO
10	28.0000	DC	0.0000	NO	YES	NO	NO	NO
11	-0.0000	NONE	-0.0000	NO	NO	NO	NO	YES
12	28.0000	DC	.2500	YES	NO	NO	NO	NO
13	15.0000	DC	-0.0000	NO	NO	NO	NO	NO
14	28.0000	DC	.2500	NO	NO	NO	NO	NO
15	-0.0000	NONE	-0.0000	NO	NO	NO	NO	YES
16	28.0000	DC	.2500	YES	NO	NO	NO	NO
17	28.0000	DC	.2500	YES	NO	NO	NO	NO
18	-0.0000	NONE	-0.0000	NO	NO	NO	NO	YES
19	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO
20	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO
21	28.0000	DC	-0.0000	NO	YES	NO	NO	NO
22	28.0000	DC	-0.0000	NO	YES	NO	NO	NO
23	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO
24	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO
25	115.0000	AC	1.0000	NO	NO	NO	YES	NO
26	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO
27	115.0000	AC	3.0000	NO	NO	NO	YES	NO
28	115.0000	AC	3.0000	NO	NO	NO	YES	NO
29	-0.0000	NONE	-0.0000	NO	NO	NO	NO	YES
30	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO
31	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO
32	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO
33	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO
34	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO
35	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO
36	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO
37	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO
38	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO
39	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO
40	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO
41	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO
42	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO
43	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO
44	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO
45	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO
46	-0.0000	NONE	-0.0000	NO	NO	NO	NO	NO

Figure 14 Continued

100127 ELECTRICAL SIGNAL FORM DATA PAGE 3

CKT NO.	START/INRUSH CURRENT AMPS	START/INRUSH CURRENT SECONDS	LOAD LOCATION	CURRENT LIMITED	IDENT.	SUMMATE	S.F. INTEGER
1	-0.0000	-0.0000	A/C + EQ.	NO	NO	NO	98561
2	-0.0000	-0.0000	EQUIPMENT	NO	NO	NO	66833
3	-0.0000	-0.0000	EQUIPMENT	NO	NO	NO	66833
4	-0.0000	-0.0000	AIRCRAFT	NO	YES	NO	49153
5	-0.0000	-0.0000	EQUIPMENT	NO	NO	NO	66833
6	-0.0000	-0.0000	NO DATA	NO	NO	NO	0
7	-0.0000	-0.0000	A/C + EQ.	NO	NO	NO	98825
8	-0.0000	-0.0000	A/C + EQ.	NO	NO	NO	98825
9	-0.0000	-0.0000	EQUIPMENT	NO	YES	NO	66833
10	15.0000	.1050	EQUIPMENT	NO	NO	NO	66833
11	-0.0000	-0.0000	NO DATA	NO	NO	NO	16385
12	-0.0000	-0.0000	EQUIPMENT	NO	NO	NO	66833
13	-0.0000	-0.0000	A/C + EQ.	NO	NO	NO	98569
14	-0.0000	-0.0000	EQUIPMENT	NO	NO	NO	66833
15	-0.0000	-0.0000	AIRCRAFT	NO	YES	NO	49153
16	-0.0000	-0.0000	EQUIPMENT	NO	NO	NO	66833
17	-0.0000	-0.0000	EQUIPMENT	NO	NO	NO	66833
18	-0.0000	-0.0000	NO DATA	NO	NO	NO	16385
19	-0.0000	-0.0000	AIRCRAFT	NO	NO	NO	32769
20	-0.0000	-0.0000	NO DATA	NO	NO	NO	1
21	15.0000	.1050	EQUIPMENT	NO	NO	NO	66833
22	15.0000	.6600	EQUIPMENT	NO	NO	NO	66833
23	-0.0000	-0.0000	NO DATA	NO	NO	NO	0
24	-0.0000	-0.0000	NO DATA	NO	NO	NO	0
25	-0.0000	-0.0000	EQUIPMENT	NO	NO	NO	66721
26	-0.0000	-0.0000	NO DATA	NO	NO	NO	4
27	-0.0000	-0.0000	EQUIPMENT	NO	NO	NO	66721
28	-0.0000	-0.0000	EQUIPMENT	NO	NO	NO	66721
29	-0.0000	-0.0000	NO DATA	NO	NO	NO	16385
30	-0.0000	-0.0000	NO DATA	NO	NO	NO	0
31	-0.0000	-0.0000	NO DATA	NO	NO	NO	0
32	-0.0000	-0.0000	NO DATA	NO	NO	NO	0
33	-0.0000	-0.0000	NO DATA	NO	NO	NO	0
34	-0.0000	-0.0000	NO DATA	NO	NO	NO	0
35	-0.0000	-0.0000	NO DATA	NO	NO	NO	0
36	-0.0000	-0.0000	NO DATA	NO	NO	NO	0
37	-0.0000	-0.0000	NO DATA	NO	NO	NO	0
38	-0.0000	-0.0000	NO DATA	NO	NO	NO	0
39	-0.0000	-0.0000	NO DATA	NO	NO	NO	0
40	-0.0000	-0.0000	NO DATA	NO	NO	NO	0
41	-0.0000	-0.0000	NO DATA	NO	NO	NO	0
42	-0.0000	-0.0000	NO DATA	NO	NO	NO	0
43	-0.0000	-0.0000	NO DATA	NO	NO	NO	0
44	-0.0000	-0.0000	NO DATA	NO	NO	NO	0
45	-0.0000	-0.0000	NO DATA	NO	NO	NO	0
46	-0.0000	-0.0000	NO DATA	NO	NO	NO	0

Figure 14 Continued

STR CKT NO.	STORE LOOP CKT. IDENT. STR. LOOP CKT.	STORE LOOP CKT. IDENT. LOOP SWITCH COMMON	LOOP LOAD CONNECTION CONN. CODE NO.	LOOP LOAD CONNECTION PIN LETTER	LOOP LOAD CONNECTION PIN L/C	MULTI WIRE CONN.	ON-STATE SOURCE	ON-STATE CIRCUIT TYPE CKT. LOAD	CKT SHT	CURR LIM.	NO CURR LIM.	OPTNL	---OFF STATE-------	INTERFACE VOLTAGE MIN.	INTERFACE VOLTAGE MAX.
1		NO	-0		NO		RETURN	NO	NO	NO	NO	NO	OPEN CIRCUIT	-13.00	16.50
2		NO	-0		NO		POWER	NO	NO	NO	YES	YES	OPTIONAL	25.00	29.00
3		NO	-0		NO		POWER	NO	YES	NO	YES	YES	OPTIONAL	25.00	29.00
4		NO	-0		NO		POWER	YES	NO	NO	YES	NO	OPTIONAL	-0.00	-0.00
5		NO	-0		NO		POWER	NO	YES	NO	YES	YES	OPTIONAL	25.00	29.00
6		NO	-0		NO			NO	NO	NO	NO	NC		-0.00	-0.00
7		NO	-0		NO		POWER	NO	NO	NO	NO	NO		0.00	16.50
8		NO	-0		NO		POWER	NO	NO	NO	NO	NO		0.00	16.50
9		NO	-0		NO		POWER	NO	NO	NO	YES	YES	OPEN CIRCUIT	25.00	28.50
10		NO	-0		NO		POWER	NO	YES	NO	YES	YES	OPTIONAL	18.00	29.00
11		NO	-0		NO		RETURN	NO	NO	NO	YES	YES	GROUNDED	-0.00	-0.00
12		NO	-0		NO		POWER	NO	YES	NO	YES	YES	OPEN CIRCUIT	25.00	29.00
13		NO	-0		NO		POWER	NO	NO	NO	NO	NO	OPEN CIRCUIT	13.50	16.50
14		NO	-0		NO		POWER	NO	NO	NO	NO	NO	OPEN CIRCUIT	-0.00	-0.00
15		NO	-0		NO		POWER	YES	NO	NO	YES	NC	OPTIONAL	-0.00	-0.00
16		NO	-0		NO		POWER	NO	YES	NO	YES	YES	OPEN CIRCUIT	25.00	29.00
17		NO	-0		NO		POWER	NO	YES	NO	YES	YES	OPEN CIRCUIT	25.00	29.00
18		NO	-0		NO		RETURN	NO	NO	NO	YES	YES	GROUNDED	-0.00	-0.00
19		NO	-0		NO		POWER	YES	NO	NO	YES	NO	OPEN CIRCUIT	-0.00	-0.00
20		NO	-0		NO		RETURN	NO	NO	NO	YES	YES	GROUNDED	-0.00	-0.00
21		NO	-0		NO		POWER	NO	YES	NO	YES	YES	OPEN CIRCUIT	25.00	29.00
22		NO	-0		NO		POWER	NO	YES	NO	YES	YES	OPEN CIRCUIT	25.00	29.00
23		NO	-0		NO			NO	NO	NO	NO	NO		-0.00	-0.00
24		NO	-0		NO			NO	NO	NO	NO	NO		-0.00	-0.00
25		NO	-0		NO		POWER	NO	NO	NO	YES	YES	OPTIONAL	108.00	121.00
26		NO	-0		NO		RETURN	NO	NO	NO	NO	NC	OPEN CIRCUIT	-0.00	-0.00
27		NO	-0		NO		POWER	NO	NO	NO	YES	YES	OPTIONAL	108.00	121.00
28		NO	-0		NO		POWER	NO	NO	NO	YES	YES	OPTIONAL	108.00	121.00
29		NO	-0		NO		RETURN	NO	NO	NO	YES	YES	GROUNDED	-0.00	-0.00
30		NO	-0		NO			NO	NO	NO	NO	NO		-0.00	-0.00
31		NO	-0		NO			NO	NO	NO	NO	NO		-0.00	-0.00
32		NO	-0		NO			NO	NC	NO	NO	NO		-0.00	-0.00
33		NO	-0		NO			NO	NO	NO	NO	NO		-0.00	-0.00
34		NO	-0		NO			NO	NO	NO	NO	NC		-0.00	-0.00
35		NO	-0		NO			NO	NO	NO	NO	NO		-0.00	-0.00
36		NO	-0		NO			NO	NO	NO	NO	NO		-0.00	-0.00
37		NO	-0		NO			NO	NO	NO	NO	NO		-0.00	-0.00
38		NO	-0		NO			NO	NO	NO	NO	NO		-0.00	-0.00
39		NO	-0		NO			NO	NO	NO	NO	NO		-0.00	-0.00
40		NO	-0		NO			NO	NO	NO	NO	NO		-0.00	-0.00
41		NO	-0		NO			NO	NO	NO	NO	NO		-0.00	-0.00
42		NO	-0		NO			NO	NO	NO	NO	NC		-0.00	-0.00
43		NO	-0		NO			NO	NO	NO	NO	NO		-0.00	-0.00
44		NO	-0		NO			NO	NO	NO	NO	NO		-0.00	-0.00
45		NO	-0		NO			NO	NO	NO	NO	NC		-0.00	-0.00
46		NO	-0		NO			NO	NO	NO	NO	NO		-0.00	-0.00

Figure 14 Continued

	183127	SUPPLEMENTARY ELECTRICAL SIGNAL FORM DATA								PAGE 2		
STP CKT NO.	MULTI-CONDUCTOR CABLE CIRCUIT	FLTG SHLD CKT.	STOPF STRUCT GROUND	LOOP CKT MAX STDY CURRENT (AMPS)	SENSOR CIRCUIT SF/LOGIC CODE NO.	MAND. CABLE TYPE	-----WIRE SIZE------ ACTUAL SIZE	MIN. A/C SIZE	MAX. A/C SIZE	CONNECTOR CODE NO.	NO CKT.	OPTIONAL INTERFACE CIRCUIT
1		NO	NO	-0.00	9021	NO	0	22	20	114	NO	NO
2		NO	NO	-0.00	-0	NO	0	20	20	114	NO	NO
3		NO	NO	-0.00	-0	NO	0	22	20	114	NO	NO
4		NO	NO	-0.00	-0	NO	0	22	20	114	NO	NO
5		NO	NO	-0.00	-0	NO	0	22	20	114	NO	NO
6		NO	NO	-0.00	-0	NO	0	22	20	114	YES	NO
7		NO	NO	-0.00	7021	NO	0	22	20	114	NO	NO
8		NO	NO	-0.00	7031	NO	0	22	20	114	NO	NO
9		NO	NO	-0.00	-0	NO	0	22	20	114	NO	NO
10		NO	NO	-0.00	-0	NO	0	22	20	114	NO	NO
11		NO	YES	-0.00	-0	NO	0	22	20	114	NO	NO
12		NO	NO	-0.00	-0	NO	0	22	20	114	NO	NO
13		NO	NO	-0.00	9011	NO	0	22	20	114	NO	NO
14		NO	NO	-0.00	6011	NO	0	22	20	114	NO	NO
15		NO	NO	-0.00	-0	NO	0	22	20	114	NO	NO
16		NO	NO	-0.00	-0	NO	0	22	20	114	NO	NO
17		NO	NO	-0.00	-0	NO	0	22	20	114	NO	NO
18		NO	YES	-0.00	-0	NO	0	22	20	114	NO	NO
19		NO	NO	-0.00	-0	NO	0	22	20	114	NO	NO
20		NO	NO	-0.00	-0	NO	0	22	20	114	NO	NO
21		NO	NO	-0.00	-0	NO	0	22	20	114	NO	NO
22		NO	NO	-0.00	-0	NO	0	22	20	114	NO	NO
23		NO	NO	-0.00	-0	NO	0	22	20	114	YES	NO
24		NO	NO	-0.00	-0	NO	0	22	20	114	YES	NO
25		NO	NO	-0.00	-0	NO	0	20	16	114	[illegible]	NO
26		NO	NO	-0.00	3011	NO	0	8	8	114	[illegible]	NO
27		NO	NO	-0.00	-0	NO	0	20	16	114	NO	NO
28		NO	NO	-0.00	-0	NO	0	20	16	114	NO	NO
29		NO	YES	-0.00	-0	NO	0	20	16	114	NO	NO
30		NO	NO	-0.00	-0	NO	-0	0	0	114	YES	NO
31		NO	NO	-0.00	-0	NO	-0	0	0	114	YES	NO
32		NO	NO	-0.00	-0	NO	-0	0	0	114	YES	NO
33		NO	NO	-0.00	-0	NO	-0	0	0	114	YES	NO
34		NO	NO	-0.00	-0	NO	-0	0	0	114	YES	NO
35		NO	NO	-0.00	-0	NO	-0	0	0	114	YES	NO
36		NO	NO	-0.00	-0	NO	-0	0	0	114	YES	NO
37		NO	NO	-0.00	-0	NO	-0	0	0	114	YES	NO
38		NO	NO	-0.00	-0	NO	-0	0	0	114	YES	NO
39		NO	NO	-0.00	-0	NO	-0	0	0	114	YES	NO
40		NO	NO	-0.00	-0	NO	-0	0	0	114	YES	NO
41		NO	NO	-0.00	-0	NO	-0	0	0	114	YES	NO
42		NO	NO	-0.00	-0	NO	-0	0	0	114	YES	NO
43		NO	NO	-0.00	-0	NO	-0	0	0	114	YES	NO
44		NO	NO	-0.00	-0	NO	-0	0	0	114	YES	NO
45		NO	NO	-0.00	-0	NO	-0	0	0	114	YES	NO
46		NO	NO	-0.00	-0	NO	-0	0	0	114	YES	NO

Figure 14 Continued

100127 ELECTRICAL LOGIC DATA PAGE 1

CKT. NO.	SIGNAL CATEGORY	RELEASE SWITCH	STN. ISOLATE	JETTISON CAPABTL.	MASTER ARM. SWITCH	GROUND SAFETY SWITCH	STORE PRES. SIG. ORIGIN
1	SENSOR	NO DATA	NO	NO DATA	NO	NO	NO DATA
2	POWER	NO DATA	NO	NO DATA	NO	NO	NO DATA
3	CONTROL	NO DATA	NO	NO DATA	NO	NO	NO DATA
4	MONITOR	NO DATA	NO	NO DATA	NO	NO	STORE
5	CONTROL	NO DATA	NO	NO DATA	NO	NO	NO DATA
6	SPARE	NO DATA	NO	NO DATA	NO	NO	NO DATA
7	SENSOR	NO DATA	NO	NO DATA	NO	NO	NO DATA
8	SENSOR	NO DATA	NO	NO DATA	NO	NO	NO DATA
9	CONTROL	NO DATA	NO	NO DATA	NO	NO	NO DATA
10	CONTROL	NO DATA	NO	NO DATA	NO	NO	NO DATA
11	POWER	NO DATA	NO	NO DATA	NO	NO	NO DATA
12	CONTROL	NO DATA	YES	NO DATA	NO	NO	NO DATA
13	SENSOR	NO DATA	NO	NO DATA	NO	NO	NO DATA
14	SENSOR	NO DATA	NO	NO DATA	NO	NO	NO DATA
15	MONITOR	NO DATA	NO	NO DATA	NO	NO	STORE
16	CONTROL	NO DATA	YES	NO DATA	NO	NO	NO DATA
17	CONTROL	NO DATA	NO	NO DATA	NO	NO	NO DATA
18	POWER	NO DATA	NO	NO DATA	NO	NO	NO DATA
19	MONITOR	NO DATA	NO	NO DATA	NO	NO	SUSP. DEV.
20	POWER	NO DATA	NO	NO DATA	NO	NO	NO DATA
21	RELEASE	R/R BUTTON	YES	NO DATA	YES	YES	NO DATA
22	RELEASE	R/R BUTTON	YES	NO DATA	YES	YES	NO DATA
23	SPARE	NO DATA	NO	NO DATA	NO	NO	NO DATA
24	SPARE	NO DATA	NO	NO DATA	NO	NO	NO DATA
25	POWER	NO DATA	NO	NO DATA	NO	NO	NO DATA
26	SENSOR	NO DATA	NO	NO DATA	NO	NO	NO DATA
27	POWER	NO DATA	NO	NO DATA	NO	NO	NO DATA
28	POWER	NO DATA	NO	NO DATA	NO	NO	NO DATA
29	POWER	NO DATA	NO	NO DATA	NO	NO	NO DATA
30	SPARE	NO DATA	NO	NO DATA	NO	NO	NO DATA
31	SPARE	NO DATA	NO	NO DATA	NO	NO	NO DATA
32	SPARE	NO DATA	NO	NO DATA	NO	NO	NO DATA
33	SPARE	NO DATA	NO	NO DATA	NO	NO	NO DATA
34	SPARE	NO DATA	NO	NO DATA	NO	NO	NO DATA
35	SPARE	NO DATA	NO	NO DATA	NO	NO	NO DATA
36	SPARE	NO DATA	NO	NO DATA	NO	NO	NO DATA
37	SPARE	NO DATA	NO	NO DATA	NO	NO	NO DATA
38	SPARE	NO DATA	NO	NO DATA	NO	NO	NO DATA
39	SPARE	NO DATA	NO	NO DATA	NO	NO	NO DATA
40	SPARE	NO DATA	NO	NO DATA	NO	NO	NO DATA
41	SPARE	NO DATA	NO	NO DATA	NO	NO	NO DATA
42	SPARE	NO DATA	NO	NO DATA	NO	NO	NO DATA
43	SPARE	NO DATA	NO	NO DATA	NO	NO	NO DATA
44	SPARE	NO DATA	NO	NO DATA	NO	NO	NO DATA
45	SPARE	NO DATA	NO	NO DATA	NO	NO	NO DATA
46	SPARE	NO DATA	NO	NO DATA	NO	NO	NO DATA

Figure 14 Continued

CKT. NO.	REL. SEQ. LOGIC	DELIV MODE LOGIC	SYSTEM POWER STATUS OFF	STDBY	OPER	OTHER	MONITOR POINT SUS.	STORE	DISPLAY SYMBOL NOMEN.	NO.	CONTROL LOGIC BREAK
1	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
2	NO	NO	NO	YES	YES	NO	NO	NO		-0	NO DATA
3	NO	NO	NO	YES	YES	NO	NO	NO		-0	SINGLE
4	NO	NO	NO	YES	YES	NO	YES	NO	STR ID	25	NO DATA
5	NO	NO	NO	YES	YES	NO	NO	NO		-0	SINGLE
6	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
7	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
8	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
9	NO	NO	NO	YES	YES	NO	NO	NO		-0	SINGLE
10	NO	NO	NO	NO	YES	NO	NO	NO		-0	SINGLE
11	NO	NO	YES	YES	YES	NO	NO	NO		-0	NO DATA
12	NO	NO	NO	YES	YES	NO	NO	NO		-0	SINGLE
13	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
14	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
15	NO	NO	NO	YES	YES	NO	YES	NO	MS PRS	58	NO DATA
16	NO	NO	NO	YES	YES	NO	NO	NO		-0	SINGLE
17	NO	NO	NO	YES	YES	NO	NO	NO		-0	SINGLE
18	NO	NO	YES	YES	YES	NO	NO	NO		-0	NO DATA
19	NO	NO	NO	YES	YES	NO	YES	NO	MS RED	55	NO DATA
20	NO	NO	YES	YES	YES	NO	NO	NO		-0	NO DATA
21	NO	NO	NO	NO	YES	NO	NO	NO		-0	NO DATA
22	YES	YES	NO	NO	YES	NO	NO	NO		-0	NO DATA
23	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
24	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
25	NO	NO	NO	YES	YES	NO	NO	NO		-0	NO DATA
26	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
27	NO	NO	NO	YES	YES	NO	NO	NO		-0	NO DATA
28	NO	NO	NO	YES	YES	NO	NO	NO		-0	NO DATA
29	NO	NO	YES	YES	YES	NO	NO	NO		-0	NO DATA
30	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
31	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
32	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
33	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
34	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
35	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
36	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
37	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
38	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
39	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
40	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
41	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
42	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
43	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
44	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
45	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA
46	NO	NO	NO	NO	NO	NO	NO	NO		-0	NO DATA

Figure 14 Continued

100127 ELECTRICAL LOGIC DATA PAGE 3

CKT. NO.	DESTIN. DIS IND	DESTIN. REC. PRCS	AIRCRAFT REC. CNTL	AIRCRAFT SPL PWR	POWER BUS	IN-FLT SET	UNIQUE LOGIC	SUSP DEV. TERM.	LOGIC INTEGER
1	NO	NO	YES	NO	NO DATA	NO	NO	NO	4194304
2	NO	NO	NO	NO	ARMAMENT POWER	NO	NO	NO	1073766400
3	NO	NO	NO	NO	ARMAMENT CONTROL	YES	NO	NO	33841152
4	NO	NO	NO	NO	NO DATA	NO	NO	NO	90624
5	NO	NO	NO	NO	ARMAMENT CONTROL	YES	NO	NO	33841152
6	NO	NO	NO	NO	NO DATA	NO	NO	NO	0
7	NO	YES	NO	NO	NO DATA	NO	NO	NO	2097152
8	NO	YES	NO	NO	NO DATA	NO	NO	NO	2097152
9	NO	NO	NO	NO	ARMAMENT CONTROL	YES	NO	NO	33841152
10	NO	NO	NO	NO	ARMAMENT CONTROL	YES	NO	NO	33832960
11	NO	NO	NO	NO	NO DATA	NO	NO	NO	28672
12	NO	NO	NO	NO	ARMAMENT CONTROL	YES	NO	NO	33841160
13	NO	NO	YES	NO	NO DATA	NO	NO	NO	4194304
14	NO	YES	NO	NO	NO DATA	NO	NO	NO	2097152
15	NO	NO	NO	NO	NO DATA	NO	NO	NO	90624
16	NO	NO	NO	NO	ARMAMENT CONTROL	YES	NO	NO	33841160
17	NO	NO	NO	NO	ARMAMENT CONTROL	YES	NO	NO	33841152
18	NO	NO	NO	NO	NO DATA	NO	NO	NO	28672
19	NO	NO	NO	NO	NO DATA	NO	NO	NO	90368
20	NO	NO	NO	NO	NO DATA	NO	NO	NO	28672
21	NO	NO	NO	NO	ARMAMENT RELEASE	NO	NO	NO	1679[illegible]801
22	NO	NO	NO	NO	ARMAMENT RELEASE	NO	NO	NO	16796873
23	NO	NO	NO	NO	NO DATA	NO	NO	NO	0
24	NO	NO	NO	NO	NO DATA	NO	NO	NO	0
25	NO	NO	NO	NO	ARMAMENT POWER	NO	NO	NO	1073766400
26	YES	NO	NO	NO	NO DATA	NO	NO	NO	1048576
27	NO	NO	NO	NO	ARMAMENT POWER	NO	NO	NO	1073766400
28	NO	NO	NO	NO	ARMAMENT POWER	NO	NO	NO	1073766400
29	NO	NO	NO	NO	NO DATA	NO	NO	NO	28672
30	NO	NO	NO	NO	NO DATA	NO	NO	NO	0
31	NO	NO	NO	NO	NO DATA	NO	NO	NO	0
32	NO	NO	NO	NO	NO DATA	NO	NO	NO	0
33	NO	NO	NO	NO	NO DATA	NO	NO	NO	0
34	NO	NO	NO	NO	NO DATA	NO	NO	NO	0
35	NO	NO	NO	NO	NO DATA	NO	NO	NO	0
36	NO	NO	NO	NO	NO DATA	NO	NO	NO	0
37	NO	NO	NO	NO	NO DATA	NO	NO	NO	0
38	NO	NO	NO	NO	NO DATA	NO	NO	NO	0
39	NO	NO	NO	NO	NO DATA	NO	NO	NO	0
40	NO	NO	NO	NO	NO DATA	NO	NO	NO	0
41	NO	NO	NO	NO	NO DATA	NO	NO	NO	0
42	NO	NO	NO	NO	NO DATA	NO	NO	NO	0
43	NO	NO	NO	NO	NO DATA	NO	NO	NO	0
44	NO	NO	NO	NO	NO DATA	NO	NO	NO	0
45	NO	NO	NO	NO	NO DATA	NO	NO	NO	0
46	NO	NO	NO	NO	NO DATA	NO	NO	NO	0

Figure 14 Continued

188127 SUPPLEMENTARY ELECTRICAL LOGIC DATA PAGE 1

STR CKT NO.	COMPATIBLE AIRCRAFT RELEASE FUNCTIONS: PYLON JETTISON	BOMB RACK	LAUNCHER	STORE INTERFACE	OPER. STATUS	COMPATIBLE MONITOR OP. FUNCTIONS: STR PRES	STR ID.	CKT SWT LOGIC	COL 34
1	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
2	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
3	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
4	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	YES	NO	YES	NO
5	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
6	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
7	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
8	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
9	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
10	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
11	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
12	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
13	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
14	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
15	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	YES	YES	NO
16	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
17	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
18	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
19	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	YES	NO	NO	YES	NO
20	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
21	NONE CHECKED	NONE CHECKED	LAUNCH JETTISON	NONE CHECKED	NO	NO	NO	NO	NO
22	NONE CHECKED	NONE CHECKED	LAUNCH NORMAL	NONE CHECKED	NO	NO	NO	NO	NO
23	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
24	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
25	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
26	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
27	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
28	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
29	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
30	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
31	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
32	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
33	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
34	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
35	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
36	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
37	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
38	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
39	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
40	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
41	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
42	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
43	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
44	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
45	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO
46	NONE CHECKED	NONE CHECKED	NONE CHECKED	NONE CHECKED	NO	NO	NO	NO	NO

Figure 14 Continued

18 0127 SUPPLEMENTARY ELECTRICAL LOGIC DATA

STR CKT NO.	STATION MONITOR POINT	POWER SIG. LOGIC	SENSOR CKT SF/LOGIC CODE NO.	STATION SELECT	OPTIONAL INTERFACE CIRCUIT
1	NO	NONE CHECKED	9021	YES	NO
2	NO	POWER SOURCE	-0	NO	NO
3	NO	NONE CHECKED	-0	NO	NO
4	NO	NONE CHECKED	-0	NO	NO
5	NO	NONE CHECKED	-0	YES	NO
6	NO	NONE CHECKED	-0	NO	NO
7	NO	NONE CHECKED	7021	YES	NO
8	NO	NONE CHECKED	7031	YES	NO
9	NO	NONE CHECKED	-0	NO	NO
10	NO	NONE CHECKED	-0	YES	NO
11	NO	POWER RETURN	-0	NO	NO
12	NO	NONE CHECKED	-0	YES	NO
13	NO	NONE CHECKED	9011	YES	NO
14	NO	NONE CHECKED	6011	YES	NO
15	NO	NONE CHECKED	-0	NO	NO
16	NO	NONE CHECKED	-0	YES	NO
17	NO	NONE CHECKED	-0	NO	NO
18	NO	POWER RETURN	-0	NO	NO
19	NO	NONE CHECKED	-0	YES	NO
20	NO	POWER RETURN	-0	NO	NO
21	NO	NONE CHECKED	-0	YES	NO
22	NO	NONE CHECKED	-0	YES	NO
23	NO	NONE CHECKED	-0	NO	NO
24	NO	NONE CHECKED	-0	NO	NO
25	NO	POWER SOURCE	-0	NO	NO
26	NO	NONE CHECKED	1011	YES	NO
27	NO	POWER SOURCE	-0	NO	NO
28	NO	POWER SOURCE	-0	NO	NO
29	NO	POWER RETURN	-0	NO	NO
30	NO	NONE CHECKED	-0	NO	NO
31	NO	NONE CHECKED	-0	NO	NO
32	NO	NONE CHECKED	-0	NO	NO
33	NO	NONE CHECKED	-0	NO	NO
34	NO	NONE CHECKED	-0	NO	NO
35	NO	NONE CHECKED	-0	NO	NO
36	NO	NONE CHECKED	-0	NO	NO
37	NO	NONE CHECKED	-0	NO	NO
38	NO	NONE CHECKED	-0	NO	NO
39	NO	NONE CHECKED	-0	NO	NO
40	NO	NONE CHECKED	-0	NO	NO
41	NO	NONE CHECKED	-0	NO	NO
42	NO	NONE CHECKED	-0	NO	NO
43	NO	NONE CHECKED	-0	NO	NO
44	NO	NONE CHECKED	-0	NO	NO
45	NO	NONE CHECKED	-0	NO	NO
46	NO	NONE CHECKED	-0	NO	NO

Figure 14 Continued

105127 ELECTRICAL SWITCHING FORM/TIME DATA PAGE 1

CIRCUIT SWITCHING FORM

STR CKT NO.	INPUT/OUTPUT	STORE INPUT CKT. FORM REQMTS. MAINT	MOMEN	PULSD	NON-SW	OPTNL	STOR OUTPUT CIRCUIT FORM	STORE OUTPUT CIRCUIT SWITCHING COMPONENT	OPTIONAL INTERFACE CIRCUIT
1	STR. OUTPUT CKT.	NO	NO	NO	NO	NO	MAINTAINED	NONE CHECKED	NO
2	STORE INPUT CKT.	YES	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
3	STORE INPUT CKT.	YES	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
4	STORE INPUT CKT.	YES	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
5	STORE INPUT CKT.	YES	NO	NO	YES	NO	NONE CHECKED	NONE CHECKED	NO
6		NO	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
7	STORE INPUT CKT.	NO	NO	NO	NO	NO	MAINTAINED	NONE CHECKED	NO
8	STORE INPUT CKT.	NO	NO	NO	NO	NO	MAINTAINED	NONE CHECKED	NO
9	STORE INPUT CKT.	YES	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
10	STORE INPUT CKT.	YES	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
11	STR. OUTPUT CKT.	NO	NO	NO	NO	NO	NON SWITCHED	NONE CHECKED	NO
12	STORE INPUT CKT.	YES	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
13	STORE INPUT CKT.	YES	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
14		NO	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
15	STORE INPUT CKT.	YES	NO	NO	YES	NO	NONE CHECKED	NONE CHECKED	NO
16	STORE INPUT CKT.	YES	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
17	STORE INPUT CKT.	YES	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
18	STR. OUTPUT CKT.	NO	NO	NO	NO	NO	NON SWITCHED	NONE CHECKED	NO
19	STORE INPUT CKT.	YES	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
20	STR. OUTPUT CKT.	NO	NO	NO	NO	NO	NON SWITCHED	NONE CHECKED	NO
21	STORE INPUT CKT.	NO	YES	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
22	STORE INPUT CKT.	NO	YES	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
23		NO	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
24		NO	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
25	STORE INPUT CKT.	YES	NO	NO	YES	NO	NONE CHECKED	NONE CHECKED	NO
26	STR. OUTPUT CKT.	NO	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
27	STORE INPUT CKT.	YES	NO	NO	YES	NO	NONE CHECKED	NONE CHECKED	NO
28	STORE INPUT CKT.	YES	NO	NO	YES	NO	NONE CHECKED	NONE CHECKED	NO
29	STR. OUTPUT CKT.	NO	NO	NO	NO	NO	NON SWITCHED	NONE CHECKED	NO
30		NO	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
31		NO	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
32		NO	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
33		NO	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
34		NO	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
35		NO	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
36		NO	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
37		NO	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
38		NO	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
39		NO	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
40		NO	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
41		NO	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
42		NO	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
43		NO	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
44		NO	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
45		NO	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO
46		NO	NO	NO	NO	NO	NONE CHECKED	NONE CHECKED	NO

Figure 14 Continued

100127 ELECTRICAL SWITCHING FORM/TIME DATA PAGE 2

CIRCUIT SWITCHING TIME

STR CKT NO.	CKT. INITIATE DELAY TIME VAR. SET	MIN. (SEC)	MAX. (SEC)	CIRCUIT ON TIME VAR. SET	MIN. (SEC)	MAX. (SEC)	INDEF	CKT. DROPOUT DELAY TIME VAR. SET	MIN. (SEC)	MAX. (SEC)	CIRCUIT (OFF) DWELL TIME VAR. SET	MIN. (SEC)	MAX. (SEC)
1	NO	-0.000	-0.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
2	NO	-0.000	-0.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
3	NO	-0.000	-0.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
4	NO	-0.000	-0.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
5	NO	-0.000	-0.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
6	NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
7	NO	-0.000	-0.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
8	NO	-0.000	-0.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
9	NO	-0.000	-0.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
10	NO	-0.000	-0.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
11	NO	-0.000	-0.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
12	NO	180.000	9999.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
13	NO	-0.000	-0.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
14	NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
15	NO	-0.000	-0.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
16	NO	-0.000	-0.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
17	NO	-0.000	-0.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
18	NO	-0.000	-0.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
19	NO	-0.000	-0.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
20	NO	-0.000	-0.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
21	NO	-0.000	-0.000	NO	.105	9999.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
22	NO	-0.000	-0.000	NO	.670	9999.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
23	NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
24	NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
25	NO	-0.000	-0.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
26	NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
27	NO	-0.000	-0.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
28	NO	-0.000	-0.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
29	NO	-0.000	-0.000	NO	-0.000	-0.000	YES	NO	-0.000	-0.000	NO	-0.000	-0.000
30	NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
31	NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
32	NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
33	NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
34	NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
35	NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
36	NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
37	NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
38	NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
39	NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
40	NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
41	NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
42	NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
43	NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
44	NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
45	NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000
46	NO	-0.000	-0.000	NO	-0.000	-0.000	NO	NO	-0.000	-0.000	NO	-0.000	-0.000

Figure 14 Continued

100127 ELECTRICAL SEQUENCE DATA PAGE 1

STR CKT NO.	EQ. INTERFACE CONNECTION CONN CODE NO.	PIN LTR	PIN L/C	INTERFACE CIRCUIT SIGNAL FUNCTION	STORE LOOP CKT. ID. PWR	RET	LOOP LOAD CONNECTION CONN CODE NO.	PIN LTR	PIN L/C	INTERFACE SIGNAL SWITCHING SEQ. ORDER	OPTIONAL INTERFACE CIRCUIT
1	114	B		PRIME FN. SIGNAL			-0			5	NO
2	114	C		SUPPORT FN. SIGNAL			-0			1	NO
3	114	D		SUPPORT FN. SIGNAL			-0			3	NO
4	114	F		SUPPORT FN. SIGNAL			-0			1	NO
5	114	G		PRIME FN. SIGNAL			-0			3	NO
6	114	H		SUPPORT FN. SIGNAL			-0				NO
7	114	K		PRIME FN. SIGNAL			-0			6	NO
8	114	L		PRIME FN. SIGNAL			-0			6	NO
9	114	N		SUPPORT FN. SIGNAL			-0			1	NO
10	114	P		SUPPORT FN. SIGNAL			-0			1	NO
11	114	U		DIRECT PWR RETURN			-0			1	NO
12	114	X		PRIME FN. SIGNAL			-0			5	NO
13	114	Y		PRIME FN. SIGNAL			-0			5	NO
14	114	Z		SUPPORT FN. SIGNAL			-0			1	NO
15	114	A	YES	SUPPORT FN. SIGNAL			-0			1	NO
16	114	B	YES	PRIME FN. SIGNAL			-0			7	NO
17	114	C	YES	PRIME FN. SIGNAL			-0			2	NO
18	114	G	YES	DIRECT PWR RETURN			-0			1	NO
19	114	H	YES	SUPPORT FN. SIGNAL			-0			4	NO
20	114	N	YES	DIRECT PWR RETURN			-0			1	NO
21	114	P	YES	PRIME FN. SIGNAL			-0			0	NO
22	114	R	YES	PRIME FN. SIGNAL			-0			8	NO
23	114	Q	YES	MISSING DATA			-0				NO
24	114	U	YES	PRIME FN. SIGNAL			-0				NO
25	114	V	YES	SUPPORT FN. SIGNAL			-0			1	NO
26	114	W	YES	PRIME FN. SIGNAL			-0			5	NO
27	114	X	YES	SUPPORT FN. SIGNAL			-0			1	NO
28	114	Y	YES	SUPPORT FN. SIGNAL			-0			1	NO
29	114	AA	YES	DIRECT PWR RETURN			-0			1	NO
30	114	A		MISSING DATA			-0				NO
31	114	E		MISSING DATA			-0				NO
32	114	J		MISSING DATA			-0				NO
33	114	M		MISSING DATA			-0				NO
34	114	R		MISSING DATA			-0				NO
35	114	S		MISSING DATA			-0				NO
36	114	T		MISSING DATA			-0				NO
37	114	V		MISSING DATA			-0				NO
38	114	W		MISSING DATA			-0				NO
39	114	D	YES	MISSING DATA			-0				NO
40	114	E	YES	MISSING DATA			-0				NO
41	114	F	YES	MISSING DATA			-0				NO
42	114	K	YES	MISSING DATA			-0				NO
43	114	M	YES	MISSING DATA			-0				NO
44	114	S	YES	MISSING DATA			-0				NO
45	114	T	YES	MISSING DATA			-0				NO
46	114	Z		MISSING DATA			-0				NO

Figure 14 Continued

OFF STATE STORE CIRCUIT DATA MATRIX

STR CKT NO.	EQ. INTERFACE CONNECTION CONN CODE NO.	PIN LTR	PIN L/C	ASSOCIATED STORE INTERFACE CIRCUITS
1	114	B		NO ENTRIES
2	114	C		NO ENTRIES
3	114	D		NO ENTRIES
4	114	F		NO ENTRIES
5	114	G		NO ENTRIES
6	114	H		NO ENTRIES
7	114	K		NO ENTRIES
8	114	L		NO ENTRIES
9	114	N		NO ENTRIES
10	114	P		NO ENTRIES
11	114	U		NO ENTRIES
12	114	X		NO ENTRIES
13	114	Y		NO ENTRIES
14	114	Z		NO ENTRIES
15	114	A	X	NO ENTRIES
16	114	B	X	NO ENTRIES
17	114	C	X	NO ENTRIES
18	114	G	X	NO ENTRIES
19	114	H	X	NO ENTRIES
20	114	K	X	NO ENTRIES
21	114	P	X	NO ENTRIES
22	114	R	X	NO ENTRIES
23	114	Q	X	NO ENTRIES
24	114	U	X	NO ENTRIES
25	114	V	X	NO ENTRIES

Figure 14 Continued

180127 ELECTRICAL SEQUENCE DATA PAGE 3

OFF STATE STORE CIRCUIT DATA MATRIX

STR CKT NO.	EQ. INTERFACE CONNECTION CONN CODE NO.	PIN LTR	PIN L/C	ASSOCIATED STORE INTERFACE CIRCUITS
26	114	W	X	NO ENTRIES
27	114	X	X	NO ENTRIES
28	114	Y	X	NO ENTRIES
29	114	AA	X	NO ENTRIES
30	114	A		NO ENTRIES
31	114	E		NO ENTRIES
32	114	J		NO ENTRIES
33	114	M		NO ENTRIES
34	114	R		NO ENTRIES
35	114	S		NO ENTRIES
36	114	T		NO ENTRIES
37	114	V		NO ENTRIES
38	114	W		NO ENTRIES
39	114	D	X	NO ENTRIES
40	114	E	X	NO ENTRIES
41	114	F	X	NO ENTRIES
42	114	K	X	NO ENTRIES
43	114	M	X	NO ENTRIES
44	114	S	X	NO ENTRIES
45	114	T	X	NO ENTRIES
46	114	Z		NO ENTRIES

Figure 14 Continued

ON STATE STORE CIRCUIT DATA MATRIX

STR CKT NO.	EQ. INTERFACE CONNECTION: CONN CODE NO.	PIN LTR	PIN L/C	ASSOCIATED STORE INTERFACE CIRCUITS
1	114	B		2 A: 4 A: 5 A: 9 A: 10 A: 11 A: 12 A: 13 A: 14 A: 15 A: 17 A: 18 A: 19 A 20 A: 21 I: 22 I: 24 A: 25 A: 26 A: 27 A: 28 A: 29 A
2	114	C		NO ENTRIES
3	114	D		NO ENTRIES
4	114	F		NO ENTRIES
5	114	G		2 A: 4 A: 7 I: 8 I: 9 A: 10 A: 11 A: 12 I: 13 I: 14 A: 15 A: 16 I: 17 A 18 A: 19 I: 20 A: 21 I: 22 I: 24 I: 25 A: 26 I: 27 A: 28 A: 29 A
6	114	H		NO ENTRIES
7	114	K		1 A: 2 A: 4 A: 5 A: 8 A: 9 A: 10 A: 11 A: 12 A: 13 A: 14 A: 15 A: 16 I 17 A: 18 A: 19 A: 20 A: 21 I: 22 I: 24 A: 25 A: 26 A: 27 A: 28 A: 29 A
8	114	L		1 A: 2 A: 4 A: 5 A: 7 A: 9 A: 10 A: 11 A: 12 A: 13 A: 14 A: 15 A: 16 I 17 A: 18 A: 19 A: 20 A: 21 I: 22 I: 24 A: 25 A: 26 A: 27 A: 28 A: 29 A
9	114	N		NO ENTRIES
10	114	P		NO ENTRIES
11	114	U		NO ENTRIES
12	114	X		1 A: 2 A: 4 A: 5 A: 7 I: 8 I: 9 A: 10 A: 11 A: 13 A: 14 A: 15 A: 16 I 17 A: 18 A: 19 A: 20 A: 21 I: 22 I: 24 A: 25 A: 26 A: 27 A: 28 A: 29 A
13	114	Y		1 A: 2 A: 4 A: 5 A: 9 A: 10 A: 11 A: 12 A: 14 A: 15 A: 17 A: 18 A: 19 A 20 A: 21 I: 22 I: 24 A: 25 A: 26 A: 27 A: 28 A: 29 A
14	114	Z		NO ENTRIES
15	114	A	X	NO ENTRIES
16	114	B	X	1 A: 2 A: 4 A: 5 A: 7 A: 8 A: 9 A: 10 A: 11 A: 12 A: 13 A: 14 A: 15 A 17 A: 18 A: 19 A: 20 A: 21 I: 22 I: 24 A: 25 A: 26 A: 27 A: 28 A: 29 A
17	114	C	X	1 I: 2 A: 4 A: 5 I: 7 I: 8 I: 9 A: 10 A: 11 I: 12 I: 13 I: 14 A: 15 A 16 I: 18 A: 19 I: 20 A: 21 I: 22 I: 24 I: 25 A: 26 I: 27 A: 28 A: 29 A
18	114	G	X	NO ENTRIES
19	114	H	X	NO ENTRIES
20	114	N	X	NO ENTRIES
21	114	P	X	19 A: 20 A: 22 I: 29 A

Figure 14 Continued

100127 ELECTRICAL SEQUENCE DATA PAGE 5

ON STATE STORE CIRCUIT DATA MATRIX

STR CKT NO.	EQ. INTERFACE CONNECTION: CONN CODE NO.	PIN LTR	PIN L/C	ASSOCIATED STORE INTERFACE CIRCUITS
22	116	R	X	1 A: 2 A: 4 A: 5 A: 6 A: 7 A: 8 A: 9 A: 10 A: 11 A: 12 A: 13 A: 14 A 15 A: 16 A: 17 A: 18 A: 19 A: 20 A: 21 I: 24 A: 25 A: 26 A: 27 A: 28 A: 29 A
23	114	O	X	NO ENTRIES
24	114	U	X	19 A: 20 A: 21 I: 22 I: 25 A: 26 A: 27 A: 28 A: 29 A
25	114	V	X	NO ENTRIES
26	114	W	X	1 A: 2 A: 4 A: 5 A: 6 A: 7 I: 8 I: 9 A: 10 A: 11 A: 12 A: 13 A: 14 A 15 A: 16 I: 17 A: 18 A: 19 A: 20 A: 21 I: 22 I: 24 A: 25 A: 27 A: 28 A: 29 A
27	114	X	X	NO ENTRIES
28	114	Y	X	NO ENTRIES
29	114	AA	X	NO ENTRIES
30	114	A		NO ENTRIES
31	114	E		NO ENTRIES
32	114	J		NO ENTRIES
33	114	M		NO ENTRIES
34	114	R		NO ENTRIES
35	114	S		NO ENTRIES
36	114	T		NO ENTRIES
37	114	V		NO ENTRIES
38	114	W		NO ENTRIES
39	114	D	X	NO ENTRIES
40	115	E	X	NO ENTRIES
41	115	F	X	NO ENTRIES
42	114	K	X	NO ENTRIES
43	114	M	X	NO ENTRIES
44	114	S	X	NO ENTRIES
45	116	T	X	NO ENTRIES

Figure 14 Continued

100127 ELECTRICAL SEQUENCE DATA PAGE 6

ON STATE STORE CIRCUIT DATA MATRIX

STR CKT NO.	EQ. INTERFACE CONNECTION CONN CODE NO.	PIN LTR	PIN L/C	ASSOCIATED STORE INTERFACE CIRCUITS
46	114	Z		NO ENTRIES

Figure 14 Continued

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS: The Phase 2 Stores Interface Data Handling Analysis (SIDHA) has accomplished its objective of augmenting the system with the capability to test aircraft/store electrical interface compatibility by a completely computerized means. This system improvement will greatly aid those agencies concerned with performing aircraft/stores compatibility tests. Although several other factors such as, mechanical fit, ground clearance, flight dynamics, and store separation characteristics, must be tested to determine the overall compatibility between the aircraft and store, the electrical compatibility testing aspects present a unique problem. It is not practical, or wise to mate a new store to an existing aircraft station electrical disconnect unless a complete electrical compatibility analysis has been accomplished. To do otherwise, may result in damage to electrical components within the aircraft or store. More seriously, an inadvertent release or firing may occur. The degree of testing provided by the Stores Interface Data Handling and Analysis System is sufficient to detect both electrical operation and/or safety incompatibilities. By having a prior knowledge of compatibility facts, the system user can readily evaluate the situation; and, if feasible, make the required aircraft wiring and/or component changes accordingly. After all incompatible conditions are corrected (and the aircraft data file is updated accordingly) the SIDHA system electrical compatibility test should be repeated to verify that all incompatible conditions have been corrected and no new ones were introduced.

The F-111E Aircraft Stores Interface was documented in the formats previously described as part of the Phase 2 development activity.

The F-4E Aircraft Stores Interface is currently being documented in the prescribed formats.

The system is available for use at AFATL now for the F-111E and F-4E. We are presently using the Aircraft Wiring Analysis program described at the 1973 symposium to define a hypothetical F-16 Aircraft Stores Interface for inclusion in the Aircraft Store Interface Data File.

This system will be of benefit to both industry and government in that it will enable an aircraft electrical compatibility study to be done early in the development phase of any new weapon. The major problem will be to get all the existing inventory of aircraft documented and put into the data file.

Additional information on this system is available in AFATL-TR-75-3 Vol I and II.

AUTOBIOGRAPHY

Capt James F. Stuart, Jr.

Capt Stuart recieved his B.S.E.E. degree in 1967 from Wichita State University and his M.S.E.E. degree in 1969 from the University of Oklahoma. He has eight years experience in aircraft/stores compatibility work and survivability/vulnerability (S/V) analysis. This experience was obtained at the Air Force Weapons Laboratory and the Air Force Armament Laboratory. Capt Stuart is a member of Tau Beta Pi Engineering Honor Society, and Eta Kappa Nu electrical Engineering Honor Society. Presently, Capt Stuart is assigned to the Air Force Armament Laboratory where he is a Project Manager working on the development of an advanced Stores Management System.

AUTOBIOGRAPHY

Michael J. Lauro

Mr Lauro attended Hofstra College and the RCA Institute and majored in mathematics and electrical technology. He has 22 years experience in the Airborne Ordnance field. The experience includes work on the F-15 Aircraft Armament Control System; and previously, the design and development of the first Integrated Armament Control System (IACS) for the Air Force. Most recently, Mr Lauro was commended for his technical report and computer-aided research and development study pertaining to the computerized analysis of aircraft/stores electrical compatibility. Presently, Mr Lauro's company, Pyrotek Data Service, is engaged in updating and expanding the aircraft and store data files he created for the Air Force Armament Laboratory, Eglin Air Force Base, Florida.

BRU 10 SIDE PLATE CORROSION STUDY

FOR

NAVAL AIR SYSTEMS COMMAND

(U)

(ARTICLE UNCLASSIFIED)

by

Kenneth Trelewicz
Dayton T. Brown, Inc.

ABSTRACT. (U) Aircraft and associated equipment corrosion problems probably date back as far as World War I. Since then, not only are millions of dollars spent in the anti-corrosion battle, but a great number of man hours also go into maintenance, repair and replacement of parts. Loss of life has been attributed to corrosion induced failures of critical aircraft parts. Increases in down time of aircraft and equipment may be traced, at least in part, to the need to fight corrosion continually and efficiently. Conditions aboard a carrier aggravate the corrosion problem by the nature of the carrier's environment. The relative scarcity of pure water aboard ship prevents anything approaching an industrial type of corrosion control operation. Corrosion removal methods are often severe because of the short time available for such activities.

Problems of corrosion are already built into the older equipment and defy practical correction, certainly by fleet level maintenance. NARF's and IMA's can and do correct some of the problems, but even at such levels only so much is possible. The Naval Air Systems Command has initiated anticorrosion efforts which involve design changes, scientific and technological research and development and improvement in overhaul and maintenance equipment and procedures.

One such program initiated at Dayton T. Brown, Inc. under the direction and funding of the Naval Air System Command involved a study of the corrosion on the BRU 10 Bomb Ejector Rack sideplates, in particular, around the hook pivot pin holes.

The purpose of this paper is to describe the approach taken, the research that was performed by Dayton T. Brown, Inc. and the programs that resulted. The areas of research involved (1) heat treatment and alloys (2) galvanic corrosion of dissimilar metals (3) exfoliation (4) stress corrosion (5) protective coatings and (6) sealants. The programs that resulted encompassed static overload testing for determining strength reduction and stress corrosion testing of the final configuration.

LIST OF APPENDICES

DISCUSSION

BACKGROUND

A report was made by Navy personnel of observations and test results from the inspection of BRU 10 bomb racks, both assembled and disassembled at various Navy facilities. The racks showed a variety of corrosion mechanisms and products that indicated there was a definite and important fleet problem with BRU 10 racks that must be corrected. In particular, severe corrosion was noted on the inside and outside of the aluminum sideplates, at the hook pivot pin holes adjacent to the hooks and at the pivot pin retaining clips. On older racks corrosion was occurring on bare anodized surfaces while on the newer racks, incorporating a protective paint system, it was occurring under the paint. Since the problem was fairly widespread and a corrective repair technique did not exist, many sets of sideplates were being rejected due to the amount of material needed to be removed to correct the situation. As a result of the above problems, an investigation was undertaken to do the following:

(1) Determine mechanisms taking place during the corrosion process.

(2) Provide recommendations for correction of the problem.

(3) If possible, supply recommendation for salvaging existing damaged sideplates.

(4) Test and evaluate recommendations

(5) Submit final configuration for incorporation into drawing package and/or repair procedures.

RESEARCH FINDINGS

First the conditions surrounding the problem had to be defined before it could be completely recognized. The sideplates are forged from aluminum 7075 and are heat treated to the T6 condition. Aluminum 7075-T6 is a high strength alloy containing high residual stresses (on the order of Ksi), due to the quenching operation. The precipitation heat treat operation, (artificial aging) at approximately 250°F does not relieve these stresses since the temperature is not high enough to cause grain growth. Ideally, after quenching, there are compressive stresses at the surface of a material and tensile stresses in its middle. Machining (including pivot hole drilling) is performed after heat treating thereby exposing high tensile stresses at the new surface. These stresses, as will be seen later, help promote certain types of corrosion. The surface of the aluminum is anodized which normally provides good corrosion protection, under most conditions.

The hook pivot pins are made of 13-8 stainless steel which is a good corrosion resistant metal. The pivot pin is installed through the holes in the aluminum sideplates in direct contact with them, and supports the hook imparting "service"

stresses not only to itself but to the area of the aluminum around the holes. The hook shoulders (chrome plated 4140 steel) come in direct contact with aluminum sideplates on the inside surfaces and a pivot pin retaining clip (stainless steel) comes in direct contact on the outside surfaces of the sideplate. The inside of the pivot pin hole and the inside of the sideplate are primed with a zinc-chromate primer while the outside surface of the sideplate contains an additional topcoat of white polyurethane paint. The complete sideplate is anodized underneath the paint.

It is well known that anodize tends to "craze" under strain. The crazing shows itself as minute cracks or discontinuities in the coating. These discontinuities make corrosion easier to occur. Since the load imparted on the hook pin is directly supported by the anodized aluminum, crazing will develop around the hook shaft areas exposing unprotected aluminum. Next there is direct contact between stainless steel and aluminum and chrome plate and aluminum. According to certain Military Specifications (eg: MIL-STD-1250, MIL-E-16400F, MIL-STD-454B and MIL-F-7179C) and many other notable references, the direct contact of these two sets of metals are not considered permissible galvanic couples and they are considered dissimilar metals. Dissimilar metals are defined as two metals or regions of metal which are chemically unlike because of a different composition, state of stress, surface condition or environment. A galvanic corrosion cell is defined as two dissimilar metals in electrical contact in the presence of an aqueous electrolyte. (eg: steel and aluminum in presence of salt atmosphere). Two points should be brought up here. It is stated in MIL-STD-1250 that the anodic layer on aluminum is ordinarily insulating, but may lose this quality after exposure to humidity and should not be depended upon for prevention of dissimilar metals contact. Also passivation of stainless steels normally protects it against corrosion. This passivation is due to the formation of a surface oxide film (reaction between surface and oxygen) which is often of monomolecular thickness. In the presence of certain contaminants, notably chloride ions, passivity may be destroyed at small discrete areas of the film. In the passive condition the stainless steels and chrome plated steels are strongly cathodic; hence they will damage other metals that are anodic, notably aluminum. Also, due to the state of stress, the aluminum is put in during quenching and according to the definition of dissimilar metals, there probably exists regions of aluminum metal around the hook shaft hole where anodic and cathodic portions are creating "corrosion cells" within the metal. Additionally the paint was not providing any additional protection since it was being worn and damaged by the action of the hook, pivot pin and retaining clip which leaves bare surfaces. As can be seen from the circumstances surrounding the problem, we were getting a combination of conditions leading to electrochemical (specifically - galvanic) corrosion, compounded by the poor exfoliation resistance of aluminum 7075-T6. It should be noted that once electrochemical corrosion starts, the chances for stress corrosion cracking of the aluminum is increased greatly. The T6 temper of 7075 is very susceptible to S. C. C. due to the unusually high residual tensile quenching stress. At the hook shaft holes, this is compounded by the fact that there are exposed tensile stresses at the surface due to machining combined with design stresses due to loads. Therefore, any method employed to help stop the electrochemical corrosion and general corrosion will certainly help to reduce the change to S. C. C.

INITIAL RECOMMENDATIONS

Based on the information gathered, the following recommendations were made: These would be used for both "in service" and newly manufactured sideplates.

(1) In service sideplates shall be stripped of anodize and inspected. New sideplates would be already in this condition. Bushing thickness to enable all corrosion products to be drilled away from hook pivot holes shall be determined. Maximum allowable bushing thickness would be 3/32". If thickness is larger, reject the sideplates.

(2) Sideplates shall be reheat treated (in service racks) or initially precipitation hardened to the T76 or T73 condition. The T73 condition provided superior exfoliation resistance with a loss of 10 - 12 % mechanical properties while T76 condition provides medium exfoliation resistance (much better than T6) with a loss of 5 - 7 % mechanical properties. The T73 condition is produced by heating the part to 350 ± 10°F for 8 hours while the T76 requires 335° +5, -10°F for 18 hours. It would have to be determined how much the reduction in mechanical properties would affect the bomb racks' performance.

(3) Once heat treated, the sideplate pivot pin holes shall be drilled to allow a 3/32" wall thickness bushing to be installed and spotfaced on the interior 1/16".

(4) Bushings are to be manufactured as follows:

(a) Material shall be 13-8 PH CRES heat treated to H-1050 condition.

(b) Bushings shall be shouldered on the inside 1/16".

(c) Bushing shall be cadmium plated in accordance with QQ-P-416C Class 1 Type 2, (.0005" thick with supplementary chromatic treatment). This provides cadmium with the corrosion resistance and cadmium is electromechanically compatible with aluminum.

(5) Sideplates (after drilling) shall be anodized in accordance with MIL-A-8625, Class 1, Type 2 with the duplex sealing operation of amendment 1, (dated 13 March 1969) of said specification used. Duplex sealing is accomplished by immersing the sideplate in a 5% solution of nickel acetate and sodium dichromate which provide additional corrosion protection over the conventional dichromate seal which had been used.

(6) After anodizing, the bushings shall be installed with a .002" press fit. The fit shall be in accordance with General Specification for Design and Construction of Aircraft Weapons System Volume 2, Rotary Wing Aircraft SD-24K.

(7) If the bushings are subjected to removal, all surfaces should be coated with fresh zinc chromate primer TT-P-1757 and installed "wet". If it is to be a permanent installation, the epoxy equivalent, MIL-P-23377 shall be used.

(8) After the primer has dried or set, a bead of polysulfide sealant MIL-S-81733 shall be applied on both sides of the bushings along the area of direct metal contact between it and the sideplate. This would keep the salt atmosphere from attacking the cadmium in direct contact with the aluminum exposing the uncompatible stainless steel.

(9) The hook pivot pins shall be 13-8 PH CRES with a coating of MIL-L-46010 dry film when applied.

(10) The same paint system (zinc chromate primer plus polyurethane topcoat) could now be applied.

(11) The Bomb Rack can now be assembled in the normal manner.

It was anticipated that these methods would provide means of repair to in service sideplates and improve the overall general and galvanic corrosion resistance of old and new sideplates at the least cost possible.

TEST AND EVALUATION

To prove out the recommendations, two bombs were manufactured with one set of sideplates T76 and one set T73 (excluding the paint system which would just retard the initial corrosion reaction) and subjected to the following tests. To determine whether the loss in mechanical properties of the sideplates had affected performance, the complete bomb racks were subjected to the design load and moments of MIL-R-21982 (detailed bomb rack specification). This test evaluates the racks' ultimate static strength based on maximum aerodynamic loads. The results of the testing showed the T76 temper to be acceptable and the T73 temper to be unacceptable based on the fact that permanent distortion was occurred in the sideplates before design limit loads were reached.

Subsequently, a third bomb rack was manufactured using the T76 non-painted "bushed" T76 sideplates and was subjected to a stress corrosion test along with a standard non-bushed T6 sideplate bomb rack. Both were subjected to in service loads while in a 5% salt spray atmosphere for 120 hours.

Results showed the bushings to completely eliminate the corrosion around the hook pivot pin holes while the T76 condition substantially increased the overall corrosion resistance of the sideplate as compared to the T6 sideplate.

CONCLUSIONS

As a result, changes have been made to the original design data package drawings to be used for procurement of new bomb racks and maintenance manuals were changed to reflect the new corrective measures to be taken to salvage in service bomb racks.

The improvements stemming from this work are expected to reduce maintenance and overhaul hours on a long term basis, increase the bomb racks' reliability and, therefore, increase aircraft availability.

CONTINUING DEVELOPMENTS

Additional work is being performed at the Naval Air Development center in conjunction with the Naval Avionics Facility in the area of sideplate finishes and preservatives. It is hoped that additional advances in primers, sealants and methods of cleaning and preserving would provide greater protection and reduce maintenance man hours.

APPENDIX I

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APPENDIX II

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Mr. Trelewicz received his Bachelors' Degree in Engineering Science from the State University of New York at Stony Brook. Major emphasis during his four years of study was placed in the mechanics/materials area. Mr. Trelewicz received his Master's Degree in Material Science from the Graduate School of the State University of New York at Stony Brook. Two major areas of concentration were Metallurgy and Mechanical Properties.

He is currently working as a Project Engineer on the testing and evaluation of mechanical and electrical systems of bomb racks and their related parts at Dayton T. Brown, Inc. Mr. Trelewicz is responsible for all phases of testing, including preparation of test procedures, troubleshooting, data analysis, etc. In particular he is responsible for all of the materials analysis, etc. eg: Metallurgical and X-Ray, being performed on armament materials. Mr. Trelewicz is a member of both the American Society for Non-Destructive Testing and the American Society for Metals.

AIRCRAFT/STORE INTERFACE MANUAL - ASIM
(U)
(Article UNCLASSIFIED)
by

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ABSTRACT. (U) Since January 1972, the joint Technical Coordination Group/Munitions Development (JTCG/MD) Working Party has sponsored the work on the Aircraft Stores Interface Manual (ASIM). The manual presents a compilation of armament interface data on aircraft, pylon and bomb racks in the form of scale drawings readily usable for aircraft clearance lines, ground lines, bomb rack hook locations, sway brace locations, pylon locations, aircraft control surfaces and other items necessary to aid in the deteternination of store-to-aircraft clearances. This manual has been accepted for this usage as a Joint Service document. Many additions, however, need to be made; such as more details on pylons, access to doors, pins, etc., aircraft carriage capabilities, etc. These are being addressed on a funds available basis and will be provided in future revisions. The next major addition planned is an addendum manual on the stores in the form of scale drawings which can be used as overlays to the basic manual. These drawings will provide store geometry and mass properties, including dimensions, weight, center of gravity, moment of inertia, tolerance when available, and basic reference information identifying the design activity and/or activity with engineering responsibility.

Since January 1972, the Joint Technical Coordination Group/ Munitions development (JTCG/MD) Working Party has sponsored the work on the Aircraft Stores Interface Manual (ASIM). The manual presents a compilation of armament interface data on aircraft, pylon and bomb racks in the form of scaled drawings. The manual is readily usable for aircraft clearance lines, ground lines, bomb rack hook locations, sway brace locations, pylon locations, aircraft control surfaces, and other items necessary to aid in the determination of store-to-aircraft clearances. The manual has been accepted for this usage as a Joint Service document. However, many items need to be added, such as more details on pylons, access (doors, pins), aircraft carriage capabilities, etc. These are being addressed on a funds available basis and will be provided in future revisions.

The aircraft designers and stores test agencies, etc. have needs for store characteristics data, just as the weapon designer has need for aircraft and suspension data. It is therefore planned to put out an addendum or supplement to the ASIM on stores. This manual will cover all stores (bombs, clusters, rockets, missiles, tanks, pods, etc.) that are attached to an aircraft through suspension equipment (racks and launchers). The drawings will describe the physical characteristics and shape of the store and provide mass properties (weight, center of gravity moment of inertia, etc.), and who has engineering responsibility (organization, code, phone number, etc.).

The first phase of this program has started with the preparation of a Joint Service Data Item Description (DID) requiring all store designers to prepare a standard format drawing to be included in the procurement package List-of-Drawings. The drawings can then be extracted, reduced and inserted into whatever manual that requires the weapon's physical data, such as ASIM.

The next phase will involve acquiring data for all existing stores and adding the data to the existing procurement package List-of-Drawings system. The third phase of the program will involve preparation, distribution, and maintenance of the manual as is being done with the ASIM. A standard format is being developed, and it is intended to acquire and present this data. It is planned to provide these drawings in the manual at a scale of 1/16" = 1". The drawings can be used as a direct overlay with the current ASIM. The original drawing will be made to a 1/4 scale and photographically reduced for direct overlay to the manual. Most drawings will be on 8 1/2" X 11" sheets; some on 11" X 17". The drawing size will be suitable for inclusion in reports, and will provide for easy storage.

There are other programs that acquire and present other data on stores and stores' requirements that complement one another without involving a duplication of effort. The armament management system "Weapon Interface Data Summary" (WIDS) books is an example of a program that will be using stores physical characteristics data. The WIDS is basically a stores electrical characteristics and requirements summary, which requires standard format stores physical characteristics data. Another example is the Weapon/Shipboard Interface Control Data books. This series of books describes the stores' requirements for shipboard handling and storage. These shipboard handling books also need store physical characteristics drawings. These two programs are planning to use the stores physical characteristics drawings.

The proposed stores physical characteristics drawings will complement many programs, as in the previous examples. The proposed drawings will alleviate the existing problems of having many different reports using their own separate data and, in many cases, using conflicting data.

LIST OF FIGURES

AIRCRAFT STORE INTERFACE MANUAL

PRESENT MANUAL

AIRCRAFT — 3 VIEW 1/16 SCALE CLEARANCE DRAWING

RACKS

AIRCRAFT/BOMB RACK INDEX CHARTS

PLANNED ADDITIONS

AIRCRAFT PYLON DRAWINGS

AIRCRAFT/PYLON WEIGHT CAPABILITIES

LAUNCHERS

STORES CHARACTERISTICS MANUAL

(AIRCRAFT/STORES INTERFACE MANUAL SUPPLEMENT)

STORES PHYSICAL CHARACTERISTICS AND MASS PROPERTIES FOR BOMBS, CLUSTERS, ROCKETS, MISSILES, TANKS, PODS.

FIG. 1

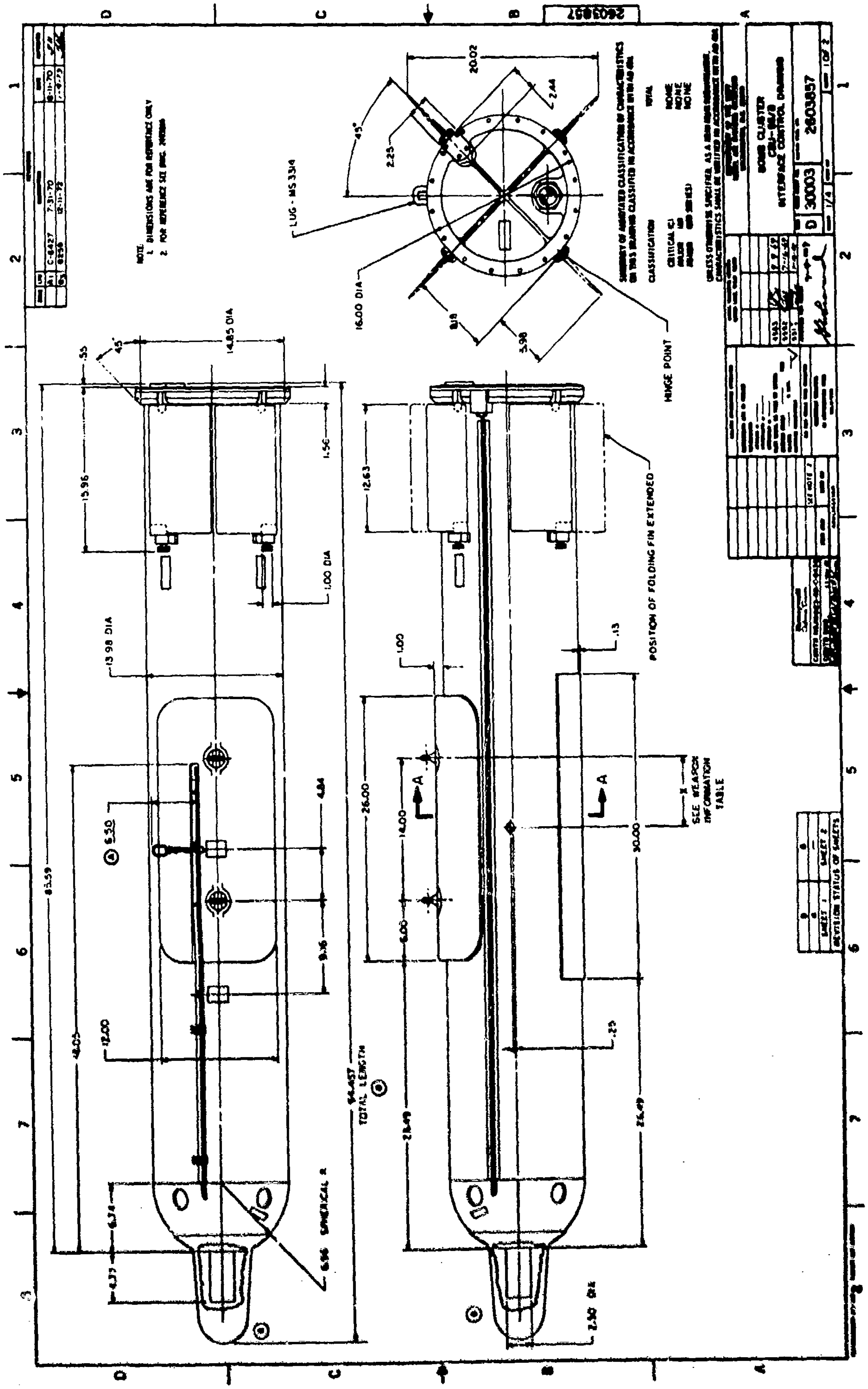
2603857
NOTE:
1. DIMENSIONS ARE FOR REFERENCE ONLY
2. FOR REFERENCE SEE DWG.
LUG - MS3314
16.00 DIA
HINGE POINT
POSITION OF FOLDING FIN EXTENDED
14.85 DIA
13.98 DIA
1.00 DIA
TOTAL LENGTH
SPHERICAL R
SEE WEAPON INFORMATION TABLE
BOMB CLUSTER
CBU-55/B
INTERFACE CONTROL DRAWING
30003
REVISION STATUS OF SHEETS

FIG. 2

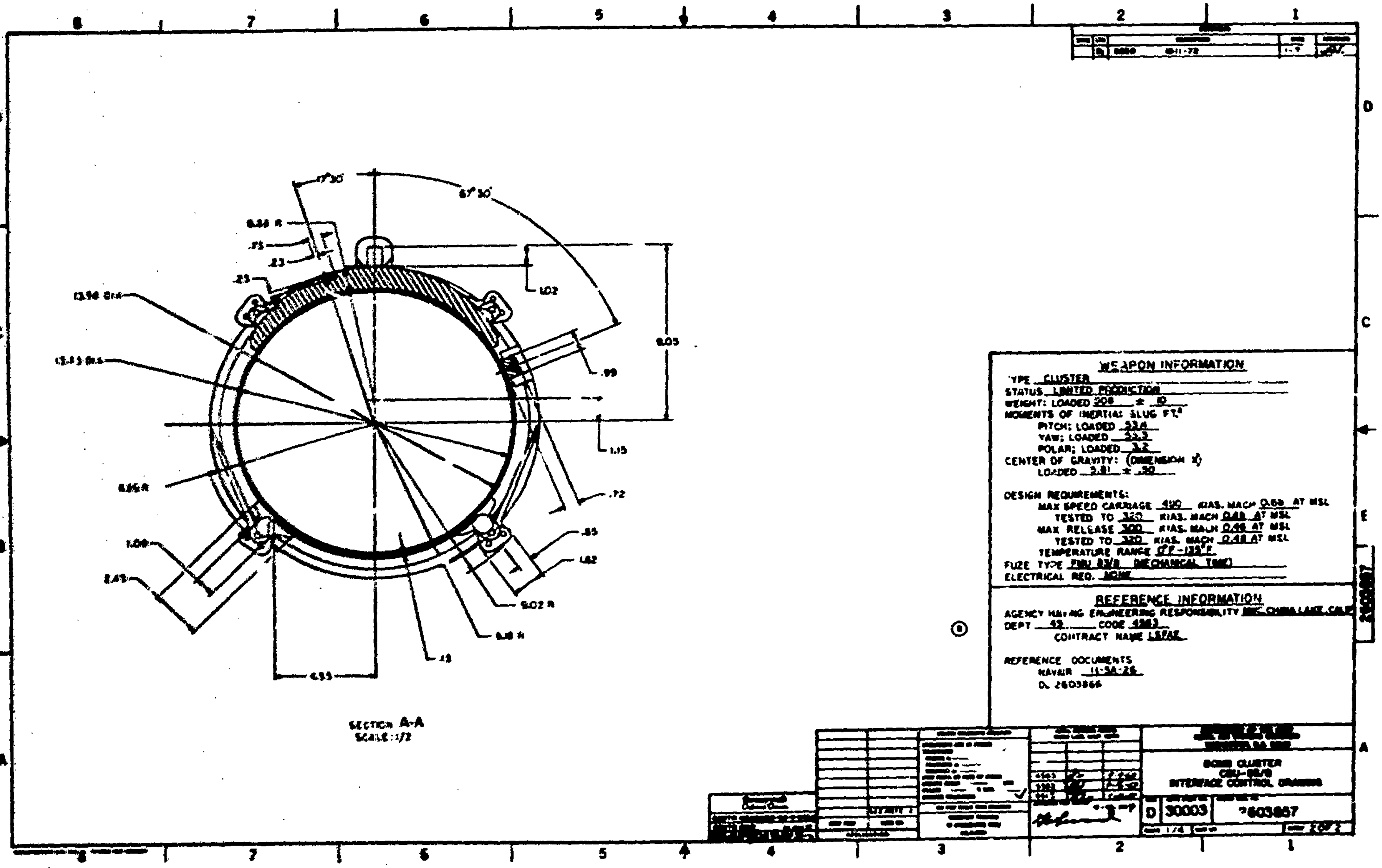
WEAPON INFORMATION
TYPE CLUSTER
STATUS LIMITED PRODUCTION
WEIGHT: LOADED 208 ± 10
MOMENTS OF INERTIA: SLUG FT.²
PITCH: LOADED 33.4
YAW: LOADED 33.3
POLAR: LOADED 3.2
CENTER OF GRAVITY: (DIMENSION X)
LOADED 2.81 ± .30
DESIGN REQUIREMENTS:
MAX SPEED CARRIAGE 410 KIAS. MACH 0.63 AT MSL
TESTED TO 320 KIAS. MACH 0.48 AT MSL
MAX RELEASE 300 KIAS. MACH 0.46 AT MSL
TESTED TO 320 KIAS. MACH 0.48 AT MSL
TEMPERATURE RANGE 0°F-135°F
FUZE TYPE FMU 83/B (MECHANICAL TIME)
ELECTRICAL REQ. NONE
REFERENCE INFORMATION
AGENCY HAVING ENGINEERING RESPONSIBILITY NWC CHINA LAKE, CALIF
DEPT 45 CODE 4563
CONTRACT NAME LSFAE
REFERENCE DOCUMENTS
NAVAIR 11-5A-26
D. 2603866
BOMB CLUSTER
CBU-55/B
INTERFACE CONTROL DRAWING
D 30003 2603857
SECTION A-A
SCALE 1/2
17°30'
67°30'
9.05
1.02
.99
1.15
.72
.85
1.82
9.02 R
8.8 R
.13
4.55
8.16 R
1.00
2.49
13.13 DIA
13.98 DIA
.25
.23
.75
8.88 R

FIG. 3

DIGITAL STORES MANAGEMENT SYSTEM
(U)

(Article Unclassified)

by

Claude M. Connell
Armament Development and Test Center
Eglin Air Force Base, Florida 32542

ABSTRACT

STORES MANAGEMENT SYSTEM

A wide variety of weapon control systems are in use today in tactical aircraft. Although their functions are similar, each system is peculiar to its aircraft or weapon. Hardware complexity is presenting a major problem by reducing overall aircraft mission reliability and aircraft flexibility. Current development of more sophisticated weapons demands a better approach to stores management.

The Armament Laboratory has initiated development of a Digital Integrated Stores Management System (SMS) capable of adapting to a wide variety of weapon systems and aircraft. The system is fully programmable providing adaptation to future weapon systems with only software changes.

The Stores Management System consists of four basic components: the pilot's control panel; the system processor; the multiplex bus; and the station logic units. The system is controlled by pilot inputs through a small number of programmable switches. The system computer processes these inputs along with other related avionics data, and sends the corresponding control signals to the station logic units over a time division multiplex bus.

The central processor for the Stores Management System is a ROLM 1602 Rugged Nova general purpose minicomputer with 32K x 16 bit word magnetic core storage. This processor provides all the control, monitor, and release signals to the system. It interfaces with the pilot and other aircraft systems as well as the stores. This unit does all data processing and controls bus transmissions between itself and all other remote terminals. The processor's software is constructed in functional blocks to allow adaptation to different aircraft and weapons without complete revision.

The pilot's control panel consists of a modified Burroughs self-scan panel with an LED switch overlay. This overlay allows the pilot to select weapon options by touching that part of the panel where the option is displayed. The 256 character display and switch points are fully programmable. The weapon control panel displays all information required for stores management and incorporates many previously hardwired weapon switches into a single display and control device.

The bus multiplexer provides a communication link between the components of the Stores Management System. This is a party line, time division multiplex system compatible with MIL-STD-1553. Information is Manchester II coded into 20 bit words; three bits for sync, 16 data bits, and one

odd parity bit. Information flow is in the following format: a command word, one through 32 data words, and a status word. Components of the mux system include a bus controller, multiplex terminal units, and the transmission line and couplers. The bus controller provides the interface between the processor and the transmission line and is under software control. The multiplex terminal units interface the transmission line to the remote terminal. The transmission line is transformer coupled, twisted, shielded pair.

The station logic unit provides the electrical interface between the SMS and the store. This unit accepts multiplexed data, decodes this data, and generates necessary control signals. The store interface consists of the following signal types: power, monitoring, control, analog, and serial. This interface is not dedicated to a particular weapon and can be programmed to control future systems.

LIST OF FIGURES

INTRODUCTION. This document describes the Stores Management System (SMS) in development at the Armament Laboratory at Eglin AFB, Florida. An overview of the system is presented explaining system objectives and advantages. Next, the general system architecture is discussed with a brief description of the major functional blocks. Finally, each functional block is discussed in detail.

OVERVIEW

The Stores Management System (SMS) is an advanced development demonstration that controls, monitors, and releases stores from a combat aircraft. The system is controlled by pilot inputs through a small number of discrete switches and a display panel. A digital computer processes these inputs and other data provided by aircraft systems and then sends control signals to the aircraft/stores interface units over a time division multiplex bus. In addition to the control, monitor, and release of stores, the SMS retains in memory preselected weapon delivery and jettison programs, provides for weapons options selections, monitors weapon status, monitors the status of avionics systems directly related to weapons delivery, provides for emergency jettison, and provides other functions detailed in this specification.

The SMS also enhances the safety, reliability, and the maintainability of stores management. All release and control signals are encoded into a multi-bit field requiring proper decoding prior to command execution. This reduces the possibility of an inadvertent release. Also, all system performance data is stored throughout the flight. This data details system errors and malfunctions which occurred during the mission and is read out after the flight by maintenance personnel.

System Architecture. The Stores Management System architecture and functional blocks are shown in Fig 1. The Stores Management System consists of four basic components: the Pilot's Control Panel; the System Processor; the Multiplex Bus; and the Station Logic Units. The system is controlled by pilot inputs through a small number of programmable switches. The system computer processes these inputs along with other related avionics data, and sends the corresponding control signals to the station logic units over a time division multiplex bus.

The central processor for the Stores Management System is a ROLM 1602 Rugged Nova general purpose minicomputer with a 32K x 16 bit word magnetic core storage. This processor provides all the control, monitor, and release signals to the system. It interfaces with the pilot and other aircraft systems as well as the stores. This unit does all data processing and controls bus transmissions between itself and other remote terminals. The processor's software is constructed in functional blocks to allow adaptation to different aircraft and weapons without complete revision.

The weapon control panel consists of an alphanumeric display media of a minimum of five lines by 10 characters/line, and a minimum of 10 programmable switches and 10 dedicated switches. The option selections are made by depressing the programmable switch associated with the desired option. The switches are positioned directly adjacent to the display area

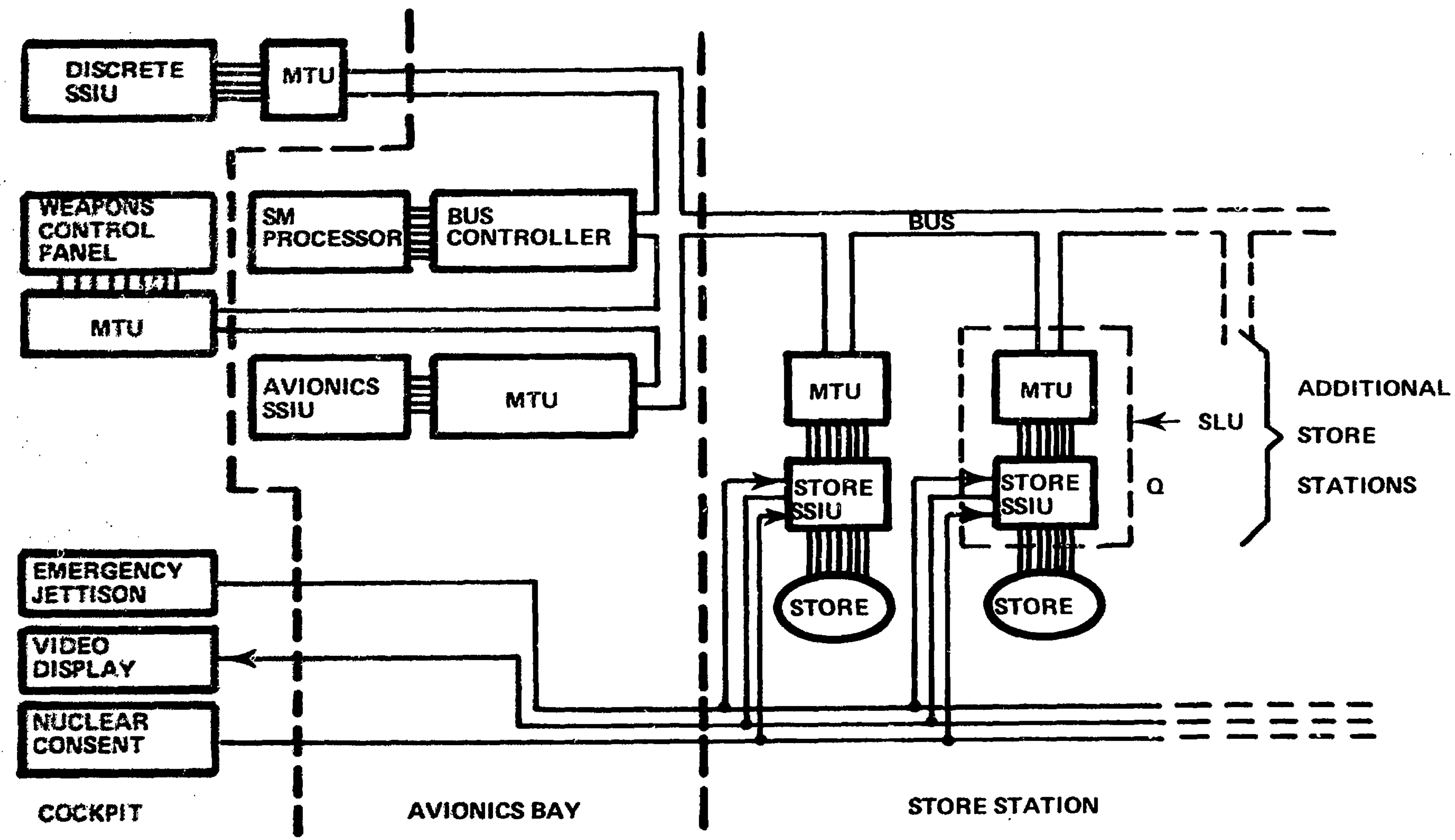

FIGURE 1 STORES MANAGEMENT FUNCTIONAL BLOCK DIAGRAM

on both sides; i.e., five switches per side. The dedicated switches are master mode switches such as power, program, program load, program clear, step display, display inventory of weapons loaded (quantity and type), program air-to-ground weapons, program air-to-air weapons, gun select, and selective jettison program. The WCP displays all information required for stores management and through the programmable switches incorporates many previously hardwired weapon switches into a single device.

The bus multiplexer provides a communication link between the components of the Stores Management System. This is a party line time division multiplex system compatible with MIL-STD-1553. Information is Manchester II coded into 20 bit words; three bits for sync, 16 data bits, and one odd parity bit. Information flow is in the following format: a command word, 1 through 32 data words, and a status word. Components of the multiplex system include a bus controller, multiplex terminal units, and the transmission line. The bus controller provides the interface between the processor and the transmission line and is under software control. Likewise, the multiplex terminal units interface the transmission line to the remote terminal. The transmission line is transformer coupled twisted shielded pairs.

The station logic unit provides the electrical interface between the SMS and the store. This unit accepts multiplexed data, decoded this data, and generates necessary control signals. The store interface consists of the following signal types: power, monitoring, control, analog, and serial. This interface is not dedicated to a particular weapon and can be programmed to control future systems.

SMS Software. The software executed in the main logic unit provides all of the control, monitor, and release signals to the system. It interfaces with the pilot and other aircraft systems as well as with the stores. The software is constructed in functional modules allowing simple adaptation to different aircraft and different weapons without complete revision. It is written in machine language and is modularly constructed to enhance debugging, and is entirely resident in the core memory of the processor. The general organization of the software is shown in Figure 2. To facilitate the functional description of the software, the individual modules have been grouped as follows:

a. Utility routines

b. Panel routines

c. Functional routines

d. Data tables

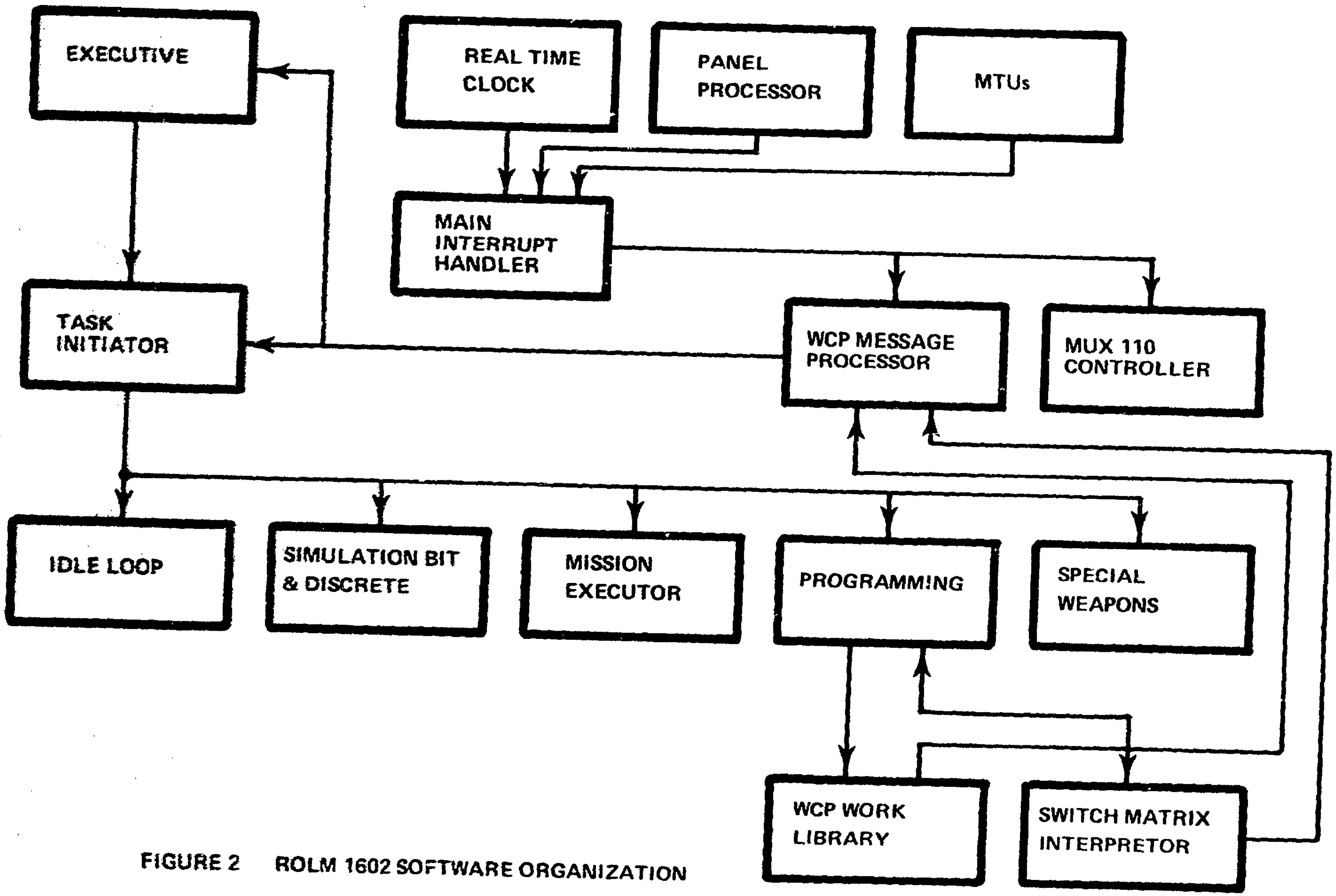

FIGURE 2 ROLM 1602 SOFTWARE ORGANIZATION

The balance of this section will describe the general operational organization of the SMS software and detail the function of individual software modules.

The utility functions performed by the SMS software are listed below:

a. Real time clock

b. Idle loop

c. Interrupt handler

d. Record history inventory

e. I/O routines

f. Power up/down

g. Buffer manager

h. Task initiator

i. Executive

The hardware real time clock is mounted on the bus controller card in the 1602. The clock is programmable for intervals between 1 and 256 milliseconds in 1 millisecond increments. At the expiration of the programmed interval, an interrupt is generated and is processed by the real time clock routine. This routine checks the time out queue and initiates any task deferred until the expiration of a given time interval. Tasks timing out simultaneously are initiated according to their relative task priorities. The real time routine returns control to the task interrupted.

The idle loop is entered when no other functional routines require execution. The module initiates periodic system status checks of the following avionics systems:

a. Avionics Remote Terminal

b. The WCP

c. Each Store SSIU

d. Each store providing feedback data

Occasional checks on static portions of the MLU are done using summing techniques. Failure of any system is relayed to the pilot via the WCP (if possible) and causes a branch to a degraded mode of operation. The idle loop is exited when another routine requires service.

The interrupt handler processes interrupts generated by the WCP, individual MTUs, or the real time clock. When an interrupt is generated, the interrupt handler determines which device caused the interrupt and transfers contol to the proper service module. The interrupt handler causes the state of the interrupted task to be saved and restores that task to operation after the interrupt has been serviced.

The record history inventory routine is entered whenever the status of any system or store needs to be recorded. Initial entry occurs on power up allowing loading of the status of the components of the SMS and the inventory of stores. Other entries occur as stores are released or systems change status. This module maintains the station inventory, stores inventory, and history tables.

The MLU software also controls I/O to the bus controller. This information consists of a command word, up to 32 data words, and a status word. The function of the I/O routines are to encode messages and control the transmission of data. The I/O routines also control message reception, decoding, and storage in the proper buffer for use by other functional routines. Simultaneous requests for I/O activity will result in the higher priority tasks receiving first attention.

The function of the Power Up/Down routines is to provide for initial system start up and for a smooth transition of program operation in the event of a power interruption. On the initial application of power to the system, this module causes a system status check to be performed and the interrogation of each SSIU by the inventory routine to determine the number and type of stores loaded on the aircraft. This information is stored in the stores inventory table. The power up routine will, at pilot option, retain or clear those preprogrammed jettison and weapons delivery routines retained in memory on power down. When these functions are complete, control is transferred to the task initiator routine to begin execution of queued tasks. The power down routine insures that the data required to restart the SMS in its current state is saved and that a message signaling MLU power failure is sent to the WCP.

The buffer manager routine allocates and de-allocates I/O buffers used by various routine and tasks. The task initiator is an executive level utility program that determines which stores management tasks are to be initiated. The tasks are listed in order of priority below:

a. Executive routine and I/O service

b. Jettison routine

c. Mission routines

d. Gun routine

e. Built-in-Test and discrete check

f. Programming

g. Idle loop

The task initiator maintains two block storage areas. The first is the Task Control Block (TCB) and contains information giving the current status of each task. This buffer is updated after program interrupt, at the completion of tasks, or at the completion of individual subtasks. The Master Control Block is a listing in priority order of the next tasks to be performed. This block contains the status of each task, whether waiting I/O, waiting for a timeout, or in execution. This data allows the task initiator routine to maintain current execution of several tasks. The task initiator exits to the service routine for the next task to be initiated.

The SMS executive changes the MLU state and the system operation mode in response to pilot inputs from the WCP or discrete switches. The executive causes the data required to restart any task to be saved in the TCB and reinitiates the highest priority task after an interrupt has been serviced.

Several routines are required to control the Weapon Control Panel (WCP) including word library, switch interpretation, and WCP message processor. The word library consists of words and symbols used in the generation of displays. The library is accessed with message codes from the stores function table and transfers these words to the panel I/O routines through the WCP message processor. The interpreter routine gathers and formats the switch information; i.e., programmable switch number, related option, and dedicated switch meanings; and transers it to the WCP message processor for use in interpreting the pilot's option or dedicated switch selection. WCP message processor receives data from the word library and switch interpreter routines, formats it for transmission to the WCP, and then transfers the data to the I/O controller. The message processor also decodes data from the WCP and loads it into memory buffers for use by the MLU. Data sent to the panel is used for message display. Data returning from the panel will consist of pilot selection commands. A record of messages sent to the WCP is also maintained. A number of non-replys will cause the MLU to issue a "WCP inoperative" message. The message processor routine also encodes commands for controlling the activation of switches on the Panel Switch Matrix.

The functional routines are the implementation of the logic required to control, monitor, and release stores. The software modules providing these functions are divided into four groups:

a. Programming

b. Mission Execution

c. Simulation

d. Special Weapons.

The programming functions are:

a. Weapon delivery options selection

b. Jettison options selection

c. Display delivery programs

d. Display jettison programs

e. Display station status

f. Continuously available options

The weapon delivery option selection routine allows the pilot to select a particular type of weapon. The options available for each weapon are stored as a permanent part of the MLU memory in the Stores Function Table. The selection process consists of displaying available options and then a pilot selection. The selection is recorded both on the display panel and in the MLU, and is followed by the display of the next set of options. This sequence is repeated until all options are selected. The operator will then have the option of storing the selected weapons delivery program or activating it. If activation is selected, the WCP will list those discrete switches (e.g., Master Arm, Geardown Safety Interlock, etc.) that must be actuated prior to the weapon release. Once these switches are "on" the WCP will indicate the displayed weapon delivery program is ready for execution.

The jettison options available to the pilot will be similarly selected. The WCP initially displays stores available for jettison. The pilot selects the store to be jettisoned and the stations from which the jettison will occur. In case the store selected is a weapon, the pilot selects either an armed or safe release. In the case of multiple weapons on a secondary rack, all weapons are released in a standard release sequence at a minimum release interval. When these options have been selected, the pilot will either activate the program or store it. If "Activate" is selected, the WCP will display the selected jettison program; and if weapons are to be jettisoned "armed", will check the status of the Master Arm. The pickle button then serves to release the store. If the Master Arm is not "on" all stores will be jettisoned safe regardless of the selection made by the pilot. If "store" is selected, the jettison program will be stored in the next available slot in the preplanned jettison area in MLU memory. These programs are then executed in a first-in-first-out manner by operation of the jettison button.

The display preplanned delivery jettison programs routine causes the stored preplanned weapons delivery programs to be displayed one at a time in the order of their selection. As each program is displayed, the pilot will have the option of changing the selection, activating the program, or displaying the next program in line. The initial pilot selection determines whether jettison programs or delivery programs are displayed.

The display station status module is entered after pilot selection of a display option and displays station by station the stores types available and the status (GO-NO/GO) of both the station and the store. The display will inform the pilot of hung weapons at the station.

The Weapons Control Panel will have three switch points continuously active during all modes of system operation. These points are:

Function	Location
Display Programs	Dedicated Switch on WCP
Change Selection	" " " "
Default/Continue	" " " "

Activation of the display programs switch will cause the software to exit the current routine and return to the display of the initial program options available to the pilot. The options displayed will be:

a. Weapons Delivery Program

b. Jettison Program

c. Display Preplanned Programs

d. Display Station Status

e. Simulation

The mission executor software accomplishes the following functions:

a. Mission Executive

b. Release/Fire

c. Safe Escape

d. Fuzing

e. Dog Fight

f. Reject

The mission executive performs a sub-executive function by responding to pilot commands from the discrete MTU. The routine is entered any time a weapons delivery program or jettison program is activated. A weapons delivery program is activated either by pilot selection of a display option on the WCP or by operation of the dog fight switch.

A jettison program is activated by pilot selection of a display option at the end of a jettison option selection sequence, or by operation of the jettison button. This routine accomplishes the following functions:

a. Transfers designated release program to the "active program" portion of memory.

b. Displays the program called up.

c. Checks the position of the Master Arm and other applicable aircraft and pilot operated interlock switches.

d. Sends message to WCP if further pilot actions are required prior to delivery.

e. Commands final store preparations.

f. Forms the required commands to be sent to the store prior to release.

g. Calls for execution of the safe escape routine at a rate not less than once every .1 second.

h. Calls the store release or trigger programs when the bomb release button, jettison button, or trigger are actuated.

i. Displays a "Program Complete" message when the delivery has been executed.

j. Responds to activation of the dog fight switch.

Activation of the bomb release switch causes the following sequence of events to be performed in the release/fire routine.

(1) A "Start Computation" message is sent to the WRC if an automatic delivery mode is selected.

(2) The position of the Master Arm and other aircraft safety interlock is checked.

(3) The pilot is informed if all interlocks requirements are not met.

(4) Arming messages are sent to all selected stations.

(5) A release counter and the release interval is set up for ripple releases.

(6) Release signals are sent to the proper station after receipt of the release signal from the WRC

(7) The record history routine is called to record the results and parameters of the release.

(8) Control is returned to the mission executor at completion of the release program.

Activation of the jettison switch causes the stores release software to perform the following functions:

a. Move the jettison program stored in the first position in the jettison stack to the "Active Program" portion of memory.

b. Store the program currently in the "Active Program" area.

c. Check Master Arm and aircraft safety interlocks.

d. Send an "Arm" command if armed jettison is selected and Master Arm is on.

e. Prepare and send release message.

f. Call record history routine.

g. Return control to mission executor at completion.

Activation of the trigger switch causes the following functions to be performed:

a. A recheck of the position of the Master Arm and other aircraft safety interlocks.

b. A check of the trigger signal to see if the gun is to be turned on or off.

c. The gun speed command is sent to the gun.

d. The fire command is sent to the gun and the current mode of gun operation is recorded.

e. Control is returned to the mission executor.

The trigger switch causes operation of the gun any time the Master Arm is on and a weapons delivery program is activated. The trigger software will not initiate operation of the lead computing optical sight (used for air-to-gun modes) unless an air-to-air gun program has been pre-programmed and activated. The gun will always fire at the high rate unless another rate is pre-programmed and that program is selected.

The safe escape routine is entered periodically from the mission executor and the stores release software. The function of this module is to obtain dive angle, airspeed, and "height above ground" data from the Air Data Computer. The program uses the dive angle and airspeed to enter the safe escape table for the selected weapon to obtain a minimum safe release altitude for fragment clearance. This altitude is compared to the height above ground. If the aircraft is below minimum safe release altitude, a warning is displayed to the pilot.

The fuzing software causes fuzing information to be transferred from the stores function table to the weapon at the proper time in the release sequence. The software is capable of sending fuze activation information to both conventional and digital fuzes.

The reject routine is entered from the mission executor after activation of the reject switch. The function of the routine is to alter the release sequence by stepping over the next store in the release order and releasing the second one in line.

The dog fight routine is entered from the mission executor after activation of the dog fight switch. The switch has four positions. The first position causes the mission executor to display the first preprogrammed weapons delivery program selected by the pilot. The second position displays the next pre-planned program selected. The third position causes the displayed program to be activated. The fourth position of the switch is neutral and causes no software interrupt.

The simulation module allows full operation of the stores management software without sending arm or fire commands to the stores. This routine is entered by pilot selection of the last "display programs" options. When the selection is made, the word "simulation" is displayed on the WCP. Once in the simulation mode, all of the SMS software functions are available to the pilot. In the simulation routine, operation of the pilot controlled discrete switches will cause the routine to compare the signal input from the discrete MIU with a standard signal stored in the MLU. Any discrepancies in coding or format will be notified of faulty switch operation. Exit from the simulation mode will occur by pilot selection of the display programs option.

The special weapons software controls the arming and monitoring of gravity nuclear weapons in a manner consistent with that specified in

Sandia Drawing 185475. This drawing specifies the sequence of commands required to arm and safe the weapon and the monitor requirements, and applies to a discrete weapon only.

Data required for proper control and monitor of aircraft stores must be maintained within the MLU memory. This is accomplished using the different data tables listed below:

a. Stores Function Table

b. Safe Escape Table

c. History Table

d. Aircraft Peculiar Table

e. Inventory Table

Weapon peculiar data is stores in a stores function table and divided into two parts; the fixed length entry and the extensive entry. The fixed length entry contains the following information:

a. Weapon code

b. Weapon characteristics

c. Nose arm pin number

d. Tail arm pin number

e. Release/fire pin number

f. Minimum release internal

g. Applicable safety interlock

h. Extension data access information

i. Release mode available

j. Number of releases per bomb button actuation

k. Employment option (disperse or separate)

l. Arming options available

The extension entry table is of variable length and contains the following types of store information:

a. The software routine controlling each individual store function.

b. The interface pin numbers to be used in controlling each individual store function.

c. The interface pin numbers to be used in monitoring store function.

d. Options available to pilot for selection.

e. WCP and MTU messages which will be used in controlling the store.

The safe escape table is a two dimensional table of minimum safe release altitudes particular to a weapon. The table is entered with dive angle and airspeed data from the Central Air Data Computer to give a minimum safe release altitude. This minimum altitude is compared with the aircraft altitude to give fragment clearance information. This table will be a permanent part of memory for all applicable stores.

The history table is formed during weapon release or jettison and contains the pilot options selected, the release parameters (dive angle, airspeed, altitude), and the results of the release when available. For releases from a multiple carriage rack, results will be stored after enough release commands have been sent to clear the rack. The results in all cases will be either "All Released" or "Store Hung."

The history table also records the results of the activation of the pilot operated discrete switches when the SMS is in the Simulate mode. The status of those stores providing feedback will also be retained in this table. The history table is updated by the record history routine.

The aircraft peculiar table contains data characteristic of the host aircraft. Data contained in this table might be the number of stations available on aircraft and safety interlocks which must be satisfied prior to store release. This module gives the SMS software the ability to be adaptable to various aircraft without major recoding. The aircraft peculiar table is a permanent part of the MLU memory.

The inventory table is divided into two parts; the stores inventory table, and the station inventory table. Both tables are constructed and maintained by software. The initial data inputs are formed from Status I information from the Stores SSIU. The stores inventory table is a store by store listing of all stores loaded on the aircraft and contains the following information:

a. Store type code

b. Address of store function table entry for the store

c. Address of safe escape table entry

d. Stations load with this store

e. Characteristics of store

This table is initialized by the inventory routine and maintained until all stores of one type are released.

The station inventory table includes:

a. Store type code
b. Parent and secondary rack type
c. Number of stores at station
d. Stores released
e. Missile status
f. Hung weapons

This table is initialized by the inventory routine and updated as stores are released or otherwise change status.

Sub-System Interface Units (SSIU). The store SSIU provides the electrical interface between the Stores Management System and the store. All store control and feedback signals must flow through the item. Functionally, the store SSIU can be divided into the following blocks.

A command word is received from the associated MTU by the timing and control section. Depending on the transmit/receive bit and subaddress mode, this section opens a channel to the specified submodule. For a particular subaddress mode, the section will compare dual transmissions to ensure proper data transfer before it is passed to the submodule. Also contained in this section is the control sequence electronic responsible for housekeeping functions such as BIT.

Data is then transmitted to or received from various I/O submodules including control section, safety interlock section, function generator, signal conditioning section, sensing section, programmable coding section, or switching section.

The control section must provide all discrete power and control signals to the store. This section is configured to provide high power, yet have many built-in safety features. Multibit codes are decoded and compared with previous transmissions (see safety interlock) before being acted upon. Both 115V 3 phase AC and 28 VDC must be switch, some circuits providing 15 amps continuous and up to 50 amps transients capacity.

The safety interlock section necessitates the ANDING of separate transmissions before activation of critical functions. The output of this section must be a one before any critical signal can be used and is constantly monitored to detect an error condition.

The function generator will provide the serial output necessary to control the B-77 digital fuze, modular weapons, and 4-6 PAL codes. The subaddress mode is decoded to determine the proper weapon interfacing procedure. For slow response weapons (such as the B-77), this section will interrogate the weapon, store the appropriate data, and deliver this data to the MIU on command. A dual serial interface is provided, one coded in Manchester II, and the other in NRZ.

The signal conditioning section contains D/A, A/D, and freq/digital convertors. The D/A convertors process digital information into analog signals acceptable for a store. An example is the slewing signal for a Maverick. The A/D converts store analog signals into a form suitable for bus transmission. The frequency/digital convertors formats a frequency into a digital form. This convertor will allow the information content of the Shrike and AIM-9 to be transmitted on the multiplex bus.

The sensing section monitors the discrete functions of the store. It must be able to detect 28 VDC, an open circuit, or a ground condition.

The programmable code section allows coding of 32 station locations, five parent rack types, nine secondary rack types, 900 store types, and up to six store quantities. The store SSIU station location and parent rack type will be programmed at pylon installation. Secondary rack type, store type, and quantity will be programmed at time of weapon upload without power on the aircraft, and will be read by the MLU at system initialization.

The switching section must switch high bandwidth analog signals (i.e., video) and route certain hardwired functions. These functions are rack unlock consent, nuclear consent, and emergency jettison. These are "hardwired" to provide safety and emergency system backup.

Communication with the store SSIU is through its associated MTU and is in MIL-STD-1553 format. A command word is first transmitted to the SSIU containing the following information:

a. A transmit receive bit.

b. A subsystem address code for internal SSIU use.

c. The number of data words to be transmitted or received.

The required data and status words follow this command word.

The store SSIU is assigned the following subsystem address codes:

Subsystem	Code
Status I	01011
Status II	01100
Control Word	01010
SIU Logic	01011
PAL Code	10111
Digital Weapon	10101

The Status I subaddress allows the MLU to read the programmable code information (see SSIU functions). This is the store loading data and is

read on system initialization. The Status II subaddress code allows the MLU to obtain store status. This code queries the sensing section and thus relays information obtained from the store monitor lines. The control subsystem address is used with data words dedicated for control functions, and will activate particular control pins. Each word consists of a 4-bit word type and three 4-bit control functions. Each control function corresponds to a particular pin set.

Communication with the store SSIU proceeds in the following sequence: Upon system power up, the MLU queries the Status I section of each SSIU in turn and informs the MLU of overall aircraft loading. The MLU then computes the pin assignment data for a particular SSIU store load. The MLU will then, and as needed throughout the mission, issue control commands to the store SSIU using the control subaddress. Periodically, the MLU will also query the sensing section to obtain store status.

The discrete SSIU provides the electrical interface for additional cockpit discrete switching including: trigger, bomb release, jettison, dog fight, reject, master arm, uncage, target designate, PAL enable, ground override, nuclear consent, and rack unlock. Activation of trigger, bomb release, jettison, dog fight, or reject causes an interrupt to be issued to the MLU. Other pilot activated switches will be queried on command. The aircraft discrete switches interfaced include gear up switch, flap interlock switch, bomb bay door sense, and gun gas purge. These switches are read periodically throughout the mission.

Also included in the discrete SSIU are A/D convertors and digital/frequency convertors. The A/D convertors digitize the two slewing signals and are sampled 60 times a second under program control. The digital/frequency convertor encodes the lock-on signals from the AIM-9 and Shrike.

The avionics SSIU provides the interface between the multiplex bus and other avionics subsystems interfacing the Stores Management System. The MLU will use data from or control the following subsystems: weapon release computer, missile firing computer, INS, and lead computing optical sight. The MLU will send to the WRC a weapon type code, a start computation signal, and release advance information. The WRC will provide the MLU with a system status signal (GO-NO/GO) and a start release signal. The Air Data computer will provide true air speed, calibrated airspeed, altitude (MSL), and altitude (AGL). The status of each component will also be provided. The inertial navigation system will provide attitude (pitch and roll), latitude, longitude, heading, and system status. The MLU will send start/stop commands to the lead computing optical sight. The required data will be loaded directly into the avionics SSIU from the systems addressed, and will be transmitted to the MLU over the multiplex bus. The avionics MIU will provide data on demand from the MLU.

Bus Multiplex System. The bus multiplexer provides a communication link between the components of the Stores Management System. The basic bus architecture conforms to MIL-STD-1553. The components of the multiplex system are the multiplex terminal units (MTU), bus controller, (BC), and the line and couplers.

The multiplex terminal units can be divided into bus interface circuitry and SSIU interface circuitry. The bus interface circuitry consists of a receiver and transmitter section. The receiver provides for input data conditioning and detection, sync code detection, data clock generation, bi-phase to NRZ conversion, and error checks of the input data. The transmitter section provides for sync code generation, parity generation, NRZ to bi-phase conversion, and bus driving circuitry. The SSIU Interface circuitry consists of a 32-word RAM, its associated control logic, the parallel data interface to the SSIU, and the control lines to the SSIU. This circuitry stores data received or data to be transmitted. It then passes the data to its associated SSIU at a one mega word rate.

The MTU, including the above mentioned sections, receives command words issued from the controller. The received command, containing the designated terminal number, commands the MTU to receive or transmit data from or to the controller or another MTU. Once an MTU is commanded to receive data and thereafter there is no activity on the data bus, the MTU will maintain its receive mode for approximately 9 micro sec, after which it will reset. While in the receive mode, it will accept any messages appearing on the data bus with the data sync code up to the quantity specified by the accepted command word. As the data words are received, they are stored in a RAM memory for subsequent transmission to the SSIU. Upon receipt of the proper quantity of data, provided the bus has no activity for 3 micro sec, a status word will be transmitted to the bus controller. If no errors are detected in the received data, the data will be transferred to the SSIU at a one mega word rate. If the MTU is commanded to transmit data, after the gap time of two to five micro seconds, the MTU will transmit its status word and initiate the SSIU to MTU data transfer.

The bus controller can also be divided into bus interface circuitry and MLU interface circuitry. The bus interface circuitry is similar to this section in the MTU. It contains the transmitter and receiver sections.

The MLU interface circuitry contains two 32-word by 16 bits RAMs, two command registers, a status register per RAM, and the necessary control lines for the MLU interface. The two command registers provide for terminal to terminal operation as do usage of the status register and the serial I/O register. Data transfer operates under program control.

The bus controller provides the interface between the MLU and the bus and operates under software control. Either RAM can be used to transmit or receive. This permits maximum flexibility allowing one RAM to be loading while the other is transmitting or receiving. The command word is loaded in the addressed command register. If the bus controller is to transmit data, the data will then be loaded into the RAM associated with the chosen command register. The controller will then transmit this data when commanded by software. If the bus controller is to receive data upon software command, the command word will be transmitted on the bus. The unit will then receive the MTU transmitted data and store it in the appropriate RAM. The MTU generated status word will be stored in the status register. After this information has been compiled, the bus controller will issue an interrupt to the MLU at signal completion. Also, located on the bus controller cards , is the programmable real time clock. This clock can be programmed to issue an interrupt between 1 - 256 milliseconds.

The line and couplers provide the transmission medium between the MTUs and the bus controller. The transmission line consists of up to 300 feet of twisted shielded pair cable. This cable has an attenuation of not more than 14 lb/100 feet and a characteristic impedance of 70 ohms at 1 megahertz. The bus couplers consist of coupling transformers and isolation resistors. The isolation resistors are 51 ohms and the termination resistors are 70 ohms.

APPENDIX I

WEAPON LIST

Racks

1. MAU-12
2. MER-10
3. AERO-3B
4. TER-9
5. AERO-7A

Conventional Weapons

1. LAU-34
2. SUU-7
3. SUU-13
4. SUU-36
5. SUU-38
6. SUU-21
7. LAU-3
8. LAU-32
9. LAU-59
10. LAU-68
11. SUU-25
12. SUU-42
13. SUU-23
14. MK84EO
15. SUU-20
16. LAU-88
17. AIM-7E

Nuclear Weapons

1. B-61
2. B-77 (Prototype)

AUTOBIOGRAPHY

Claude M. Connell

Mr Connell received his B.S. in Engineering (Electrical) from Mississippi State University and is now enrolled in a Master of Science program at the University of Florida. For the past two years, he has worked in aircraft/stores compatibility and control, particularly in the application of multiplexing and digital processing. Presently, Mr Connell is assigned to the Air Force Armament Laboratory where he is a project manager of an advanced Stores Management System.

INTEGRATION OF A TWO STAGE PEDRO/RECRUIT ROCKET WITH THE F-4J AIRCRAFT FOR THE FIGHTER LAUNCHED ADVANCED MATERIALS EXPERIMENT (FLAME)

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ABSTRACT

As part of the overall Tri-Service Advanced Ballistic Missile Reentry System (ABRES) Program, the Defense Nuclear Agency (DNA) is currently investigating the coupled erosive/ablative effects of high altitude hydrometer environments on reentry vehicle heatshield and nosetip materials. For this purpose, the concept of utilizing an F-4J airplane as launch platform for the Pedro-Recruit booster payload combination was proposed as the Fighter Launched Advanced Materials Experiment (FLAME).

The project involved the integration of the Pedro-Recruit on the F-4J airplane and the release of this store during supersonic flight. The Pedro-Recruit rocket is a 25.7 foot long, 3,870 pound two stage rocket. Nominal reentry vehicle velocity in the experimental region of interest at 35,000 feet is approximately 14,000 feet per second. A matrix of initial energy conditions which would yield desired vehicle performance was developed by the Pedro-Recruit manufacturer, Aerojet Liquid Rocket Corporation. From this matrix, a nominal release condition of 1.3 Mach, 55,000 feet and 30 degrees nose up flight path angle was chosen based on predicted aircraft performance. Pedro-Recruit ignition is commanded after apogee at 13 degrees nose down flight path angle approximately 26 seconds after release. The size of this store caused several unique problems in integrating the store with the airplane. The solution to these problems resulted in an installation with the store canted four degrees horizontally with respect to the airplane centerline and foldable first stage fins. Analysis and flight tests were conducted to verify the structural integrity of this installation as well as to assess the effect of the store on the flying qualities and performance of the airplane.

The unique carriage configuration also generated interest in the supersonic separation characteristics of the store from the airplane. In order to assess these characteristics, captive trajectory separation tests were conducted at Arnold Engineering Development Center (AEDC) Tullahoma, Tennessee. Based on the data obtained from these simulations and analysis of the separation conditions, sufficient data were gathered to obtain a flight clearance for release of this store. Initial dummy separations were conducted at the Tonopah Test Range with live firings successfully conducted at the Naval Air Test Center (NAVAIRTESTCEN) Patuxent River, Maryland.

This program demonstrated the successful use of store separation prediction techniques to safely clear a new store in a portion of the F-4J flight envelope where store separations had not been previously attempted. In doing this, several novel innovations in store suspension equipment were tested and successfully used in the program.

INTRODUCTION

In April 1974, the Defense Nuclear Agency (DNA) requested the U. S. Naval Air Test Center (NAVAIRTESTCEN) to study the feasibility of launching an Aerojet Liquid Rocket Corporation (ALRC) Pedro-Recruit two stage rocket booster with nosetip reentry vehicle from the F-4J airplane. The program, termed Fighter Launched Advanced Materials Experiment (FLAME), was initiated as an extension of current programs designed to collect missile nosetip erosion data. The specific FLAME program objective is to collect coupled erosion/ablation data derived from reentry vehicles traversing a hydrometer environment under specific reentry conditions.

From a Pedro-Recruit energy analysis, these reentry conditions established a matrix of acceptable Pedro-Recruit initial conditions for release. It was then necessary to correlate the analytically derived performance of the F-4J/Pedro-Recruit combination with release conditions required for nominal rocket performance.

Initial analysis indicated that F-4J airplane performance could satisfy initial release energy requirements. Having established this fact, further analysis was commenced to determine F-4J/Pedro-Recruit integration requirements.

DESCRIPTION OF EQUIPMENT

F-4J Airplane

The F-4J airplane is a two place (tandem), supersonic, long-range, all weather fighter built by McDonnell Aircraft Corporation. The airplane is designed for intermediate and long range high altitude interceptions using missiles as the principle armament and for intermediate or long range attack missions to deliver airborne weapons/stores. The airplane is powered by two single rotor, axial flow, variable stator turbo-jet J79-GE-10 engines with afterburner. The airplane features a low mounted swept-back wing with anhedral at the wing tips and a one-piece stabilizer with cathedral, mounted low on the aft fuselage. The aircraft has the capability to carry and release external stores from four wing mounted and one centerline station. The basic suspension equipment in the centerline station is the internal AERO-27/A bomb rack.

Pedro-Recruit

The Pedro-Recruit is a two-stage solid propellant rocket manufactured by Aerojet Liquid Rocket Corporation. The payload is recoverable after separation from the second stage. The rocket is 25.7 feet long and weighs 3,870 pounds (figure 1). The first stage, Pedro, has a diameter of 30 inches, while the second stage, Recruit, diameter is 9 inches. Pedro-Recruit is stabilized by four orthogonal fins. In order to provide additional ground clearance, two of the fins are rotated out of the orthogonal configuration about the rocket longitudinal axis for carriage (figure 2). The fins deploy to the orthogonal configuration pyrotechnically 0.5 seconds after release. The first stage has two motor fire enabling devices in series, a pilot operated switch, and a lanyard pull wire. First stage ignition is initiated by command from the control center through the onboard command receiver. A mechanical

timer provides an alternate ignition initiation. First stage burn time is 11.0 seconds. Pressure reduction in the first stage chamber ignites the second stage. Second stage ignition operates a blast diaphragm which releases the first stage. The pressure change at second stage burnout separates the payload.

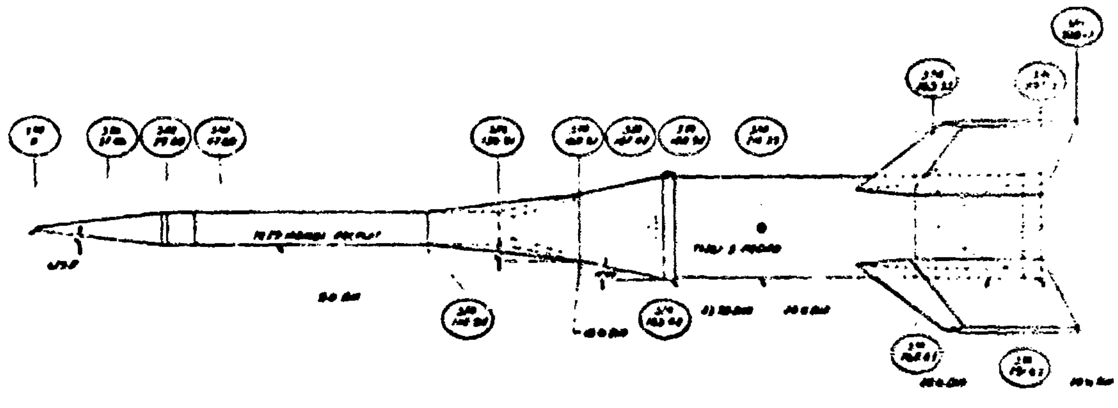

Figure 1
Pedro-Recruit Rocket

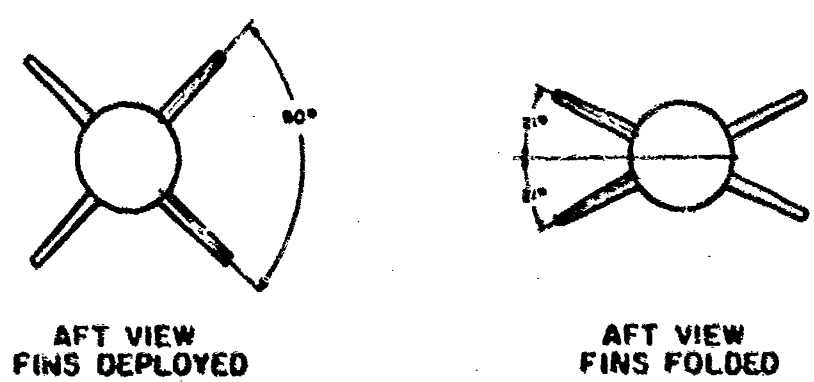

Figure 2
Fin Deployment Geometry

PROGRAM OUTLINE.

The program to integrate the Pedro-Recruit rocket with the F-4J was divided into four segments. These were:

a. Design and implementation of the electrical and mechanical interface required to mate the Pedro-Recruit with the F-4J airplane.

b. Analysis and wind tunnel verification of flight loads imposed by the Pedro-Recruit on the F-4J and of the performance of the F-4J/Pedro-Recruit combination

c. Determination of any airplane flight restrictions resulting from carriage of the Pedro-Recruit.

d. Determination of the separation behavior of the Pedro-Recruit from the F-4J at the desired release flight conditions.

The completion of this program resulted in sufficient hardware to conduct the test program and sufficient data to allow the Naval Air Systems Command to issue a clearance to conduct the test flights. The remainder of this paper will cover the details of each of these program segments.

Electrical/Mechanical Interface

The McDonnell Aircraft Corporation (MCAIR) was tasked by DNA to, with NAVAIRTESTCEN assistance, develop the required electrical and mechanical interfaces to allow carriage and operation of the Pedro-Recruit vehicle on the F-4J airplane. The design guidelines established were that the installation would be quickly transferrable between F-4J airplanes and that the F-4J airplane used not be structurally modified for the program. This last requirement was a result of a desire to retain the standard operational configuration of F-4J airplanes at NAVAIRTESTCEN as well as a desire to provide flexibility in airplane availability. An additional program constraint was that only 12 weeks were available between program initiation and first separation test flight. To follow the design guidelines in the program time frame, existing armament suspension equipments mechanically compatible with the F-4J airplane were examined for possible use in carrying the Pedro-Recruit vehicle. An examination of the available equipments indicated that the 78 inch suspension LAU-77A/A Standard Arm Missile Launcher was a viable mechanical interface for use in the FLAME program. Further analysis indicated that the LAU-77A/A with five MK-9 MOD-0 cartridges would provide a relatively high end of stroke separation velocity for the Pedro-Recruit missile (figure 3) which was expected to enhance the separation characteristics from the F-4 airplane. Asymmetrical airplane load considerations constrained the carriage location of the Pedro-Recruit to the F-4J centerline station, hence installation of the LAU-77A/A on the F-4J AERO-27A centerline bomb rack was examined and found mechanically feasible for the airplane/rocket interface. Upon tentative selection of the LAU-77A/A, the only remaining design parameter to be fixed was the longitudinal position of the Pedro-Recruit relative to the launcher. The location of the Pedro-Recruit was being driven by several conflicting requirements. The first requirement indicated that the vehicle should be moved relatively far aft with respect to the launcher so as not to interfere with the F-4J nose gear retraction cycle. However, placing the Pedro-Recruit far enough aft to move the nosetip of the Pedro-Recruit out of the nose gear retraction arc would have exceeded both the aft center of gravity location restriction on the airplane and the AERO-27A structural limitations and, in addition, would have imposed unrealistic rotation limitations on the airplane during takeoff and landing. The airplane takeoff/landing rotation limitations arose from the marginal clearance between the undeployed Pedro-Recruit fins and the ground. Two proposed solutions to these conflicting requirements were first to design a pivoting mount for the launcher which would rotate the Pedro-Recruit out of the

gear retraction arc during takeoff and landing and second to mount the Pedro-Recruit yawed from the aircraft centerline to keep the Pedro-Recruit out of the gear retraction arc at all times. Both these alternatives provided adequate rotational clearance, acceptable structural loads on the AERO-27A, and a satisfactory airplane center of gravity location. The only solution to the installation requirements which could be implemented within the program time constraint was to mount the rocket yawed 4° nose right with respect to the airplane centerline moving the vehicle nosetip out of the F-4J nose gear retraction path. The suspension hardware of the LAU-77A/A was strengthened and modified to provide the required 4° yaw and an aerodynamic fairing added between the LAU-77A/A and the AERO-27A to minimize performance loss due to the rack installation. The resulting installation is shown in figure 4.

The electrical requirements of the Pedro-Recruit were supplied using existing circuitry in the airplane. The FLAME Control Panel was inserted in the starboard console in place of the DCU-75/A Special Weapons Control Panel. A connector adapted it to the Special Weapons wiring.

An adapter harness was manufactured to connect the centerline Special Weapons Connector and centerline Multiple Weapons Release Connector to the LAU-77A/A. Internally, the LAU-77A/A was modified such that the Multiple Weapons Release Circuitry was connected to the launcher cartridge firing system, thus allowing the use of the normal Multiple Weapons Release System for release of the Pedro-Recruit rocket. The remaining wiring, from the Special Weapons circuit, was fed through the launcher to a connector at the aft end. A second wire bundle was then utilized between the LAU-77A/A aft connector and Pedro-Recruit connector. By using existing electrical circuitry in the F-4, the effort required to electrically adapt the Pedro-Recruit to the airplane was minimized.

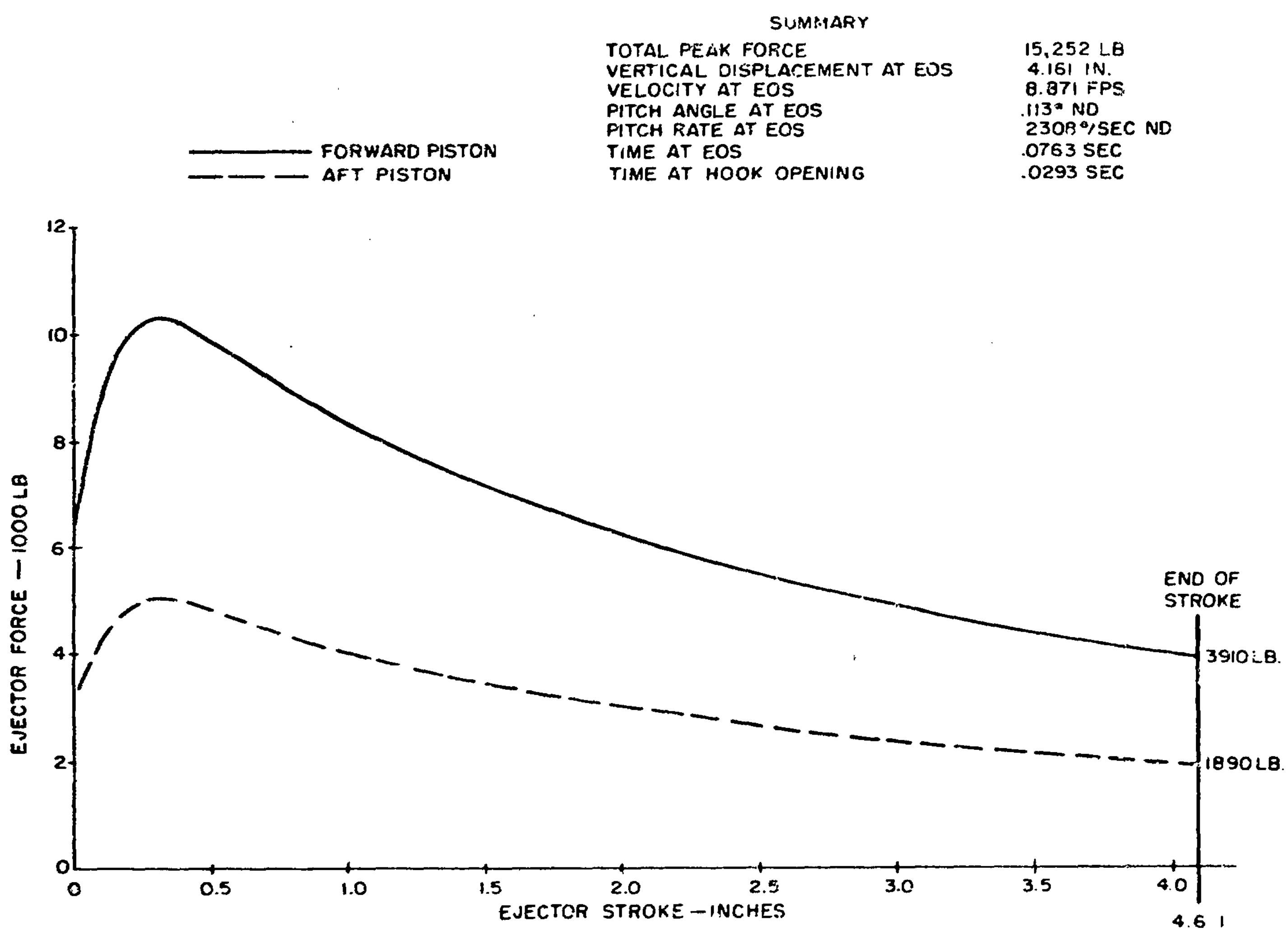

Figure 3
LAU-77A/A Launcher Characteristics

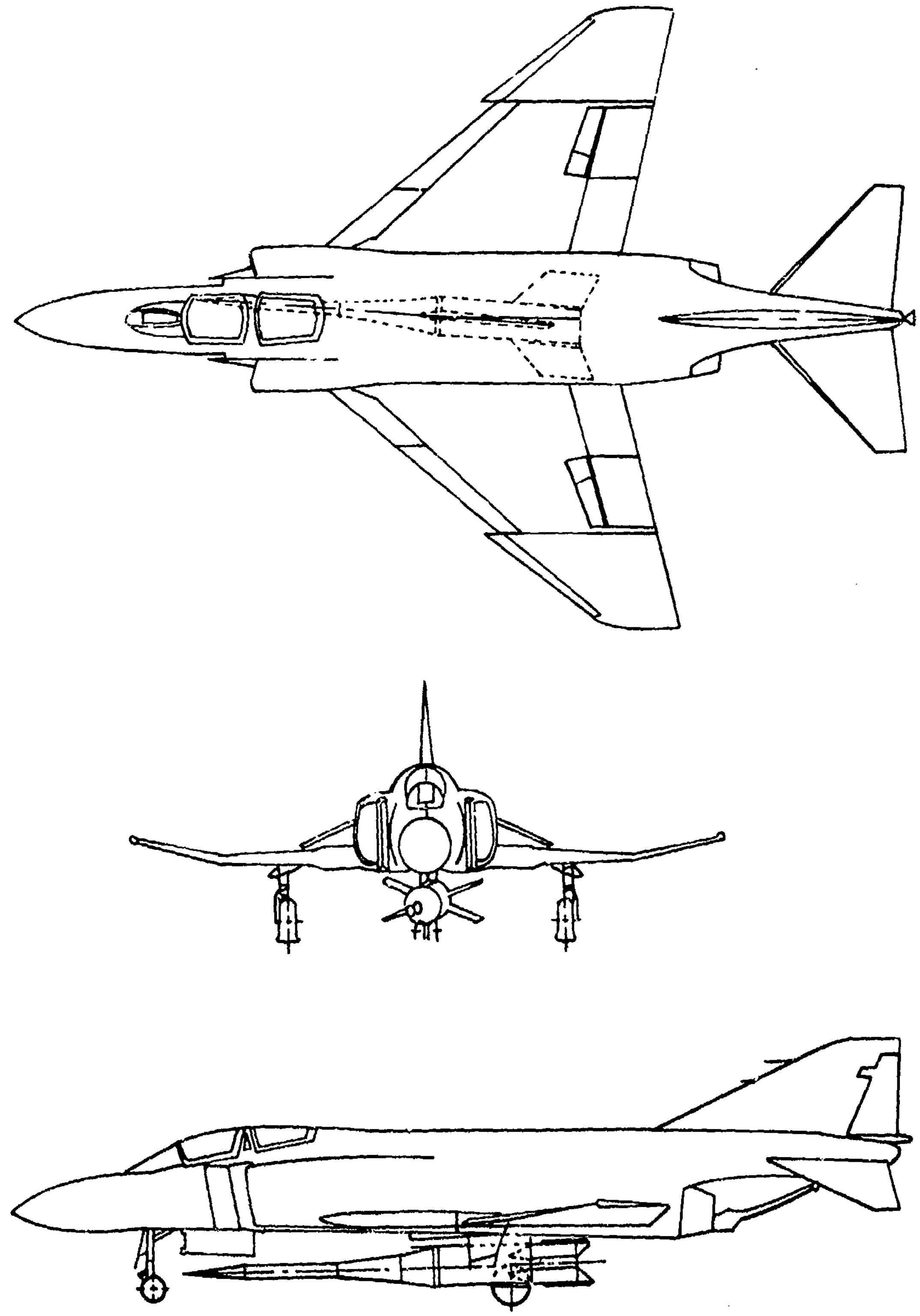

Figure 4
F-4J with Pedro-Recruit

Loads Analysis and Performance

A loads analysis was conducted to determine the structural capability of the F-4J airplane to withstand the loads imposed during carriage of the Pedro-Recruit rocket. In the captive installation, the store is mounted on the F-4J centerline 4° nose right and 2° nose down. Loads data for this configuration were obtained during a wind tunnel test of a 5% scale model in the 4 foot continuous flow transonic tunnel, at the Arnold Engineering Development Center (AEDC), Tullahoma, Tennessee. Based on these loads data MCAIR provided the following captive carriage envelope for the Pedro-Recruit on the F-4J:

Speed Placard (shown in figure 5):

Sea level to 40,000 ft - 450 KCAS

40,000 ft and above - 525 KCAS or M =1.8 (whichever is less)

Maneuvering Envelope:

Vertical load factor: n_z =-1.0 to 4.0

Stick throw limited to gradual coordinated turns

Gust Velocity: lateral gust velocity of 25 fps at maximum speed of 525 KCAS

Airplane Trim: trim as required to maintain zero lateral acceleration.

Analysis of the flight envelope indicated that maximum loads occur on the 525 KCAS speed placard. A summary of these load conditions is presented in table I. The analysis considered the F-4J being trimmed 0.5 degrees nose left (producing zero lateral acceleration) to compensate for the side load on the Pedro-Recruit due to its 4° yaw installation.

The incremental drag of the Pedro-Recruit rocket installed on the F-4J was derived from data obtained in AEDC wind tunnel testing. This increment was obtained by testing the F-4J model with and without the store and launcher installed. A curve of the incremental drag coefficient as a function of Mach number is shown in figure 6.

The nominal profile for the acceleration and climb to the launch point is shown in figure 7. Table II gives a detailed breakdown of the climb and the nominal launch conditions.

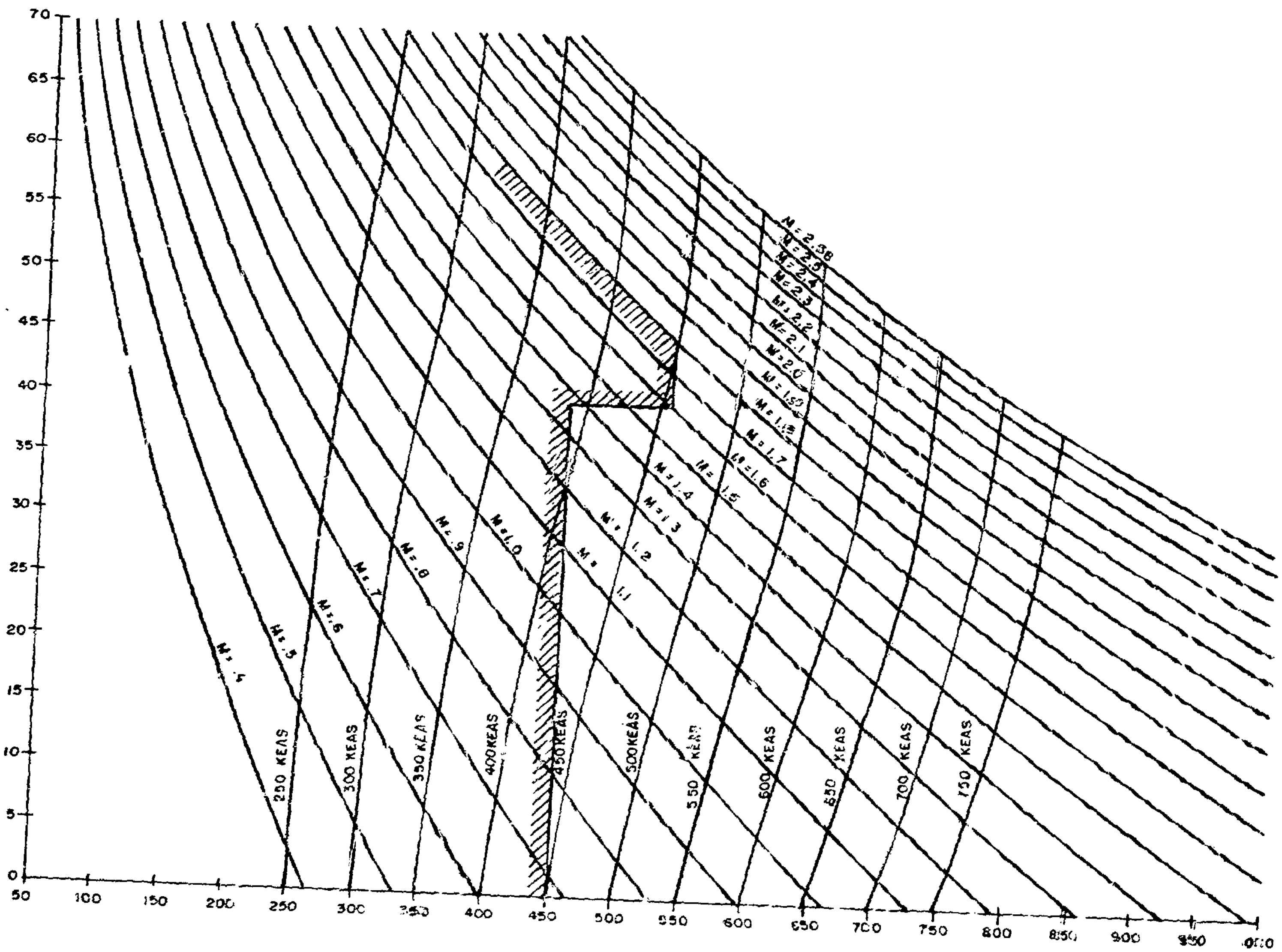

Figure 5
F-4J/Pedro-Recruit Speed Altitude Envelope

Table I

LAUNCHER LOADS

CONDITION					ULTIMATE LOADS					
M	Alt	n_z	n_y		V	S	MY	MZ	MX	D
1.6	40000	4.0	.176	Rocket	-29544	-3900	312000	10500	-53500	4750
				Launcher	-1200	-597	--	--	--	--
		1.0	.176	Rocket	-14110	-3850	356000	45000	-57500	4750
				Launcher	-300	-550	--	--	--	--
		-1.0	.176	Rocket	-1600	-3200	296000	36900	-46500	4750
				Launcher	300	-1420	--	--	--	--
1.8	46000	4.0	.166	Rocket	-29940	-4150	320000	17700	-50500	4730
				Launcher	-1200	-187	--	--	--	--
		1.0	.166	Rocket	-14160	-3950	380000	38200	-39600	4730
				Launcher	-300	-400	--	--	--	--
		-1.0	.166	Rocket	-1100	-3400	382000	48000	-342000	4730
				Launcher	300	-1420	--	--	--	--

NOTES:
1. Loads referenced to respective c.g. of Pedro-Recruit and Launcher.
2. Lateral gust velocity: 25 FPS.
3. F-4J trimmed 0.5° nose left.
4. Legend: V - vertical load, S - side load, MY - pitching moment, MZ - yawing moment, MX - rolling moment, D - drag load.
5. Sign convention: V(+up), Y (+left), MY(+nose up), MZ(+nose left), MX(+roll rt), D(+aft)

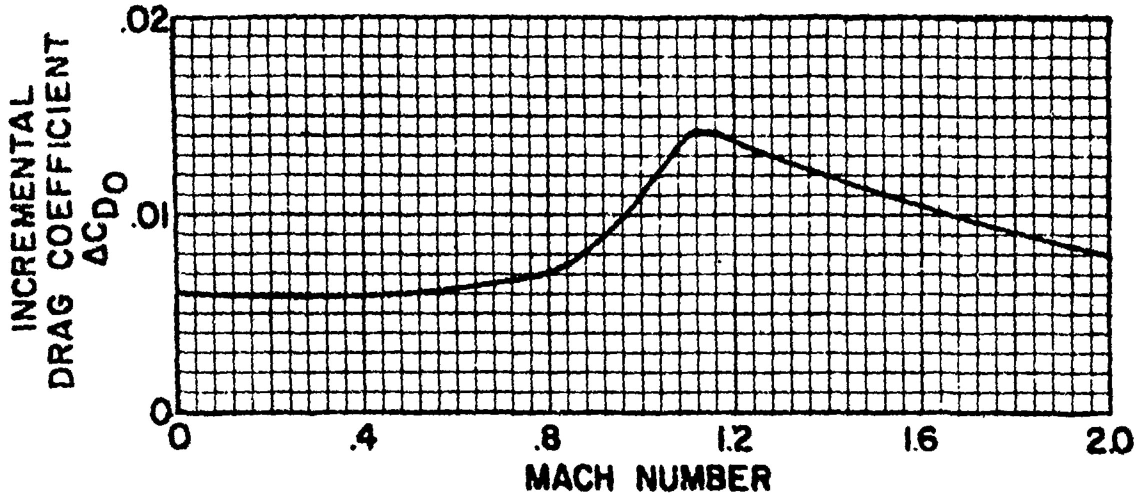

Figure 6
Pedro-Recruit Installed Drag Increment

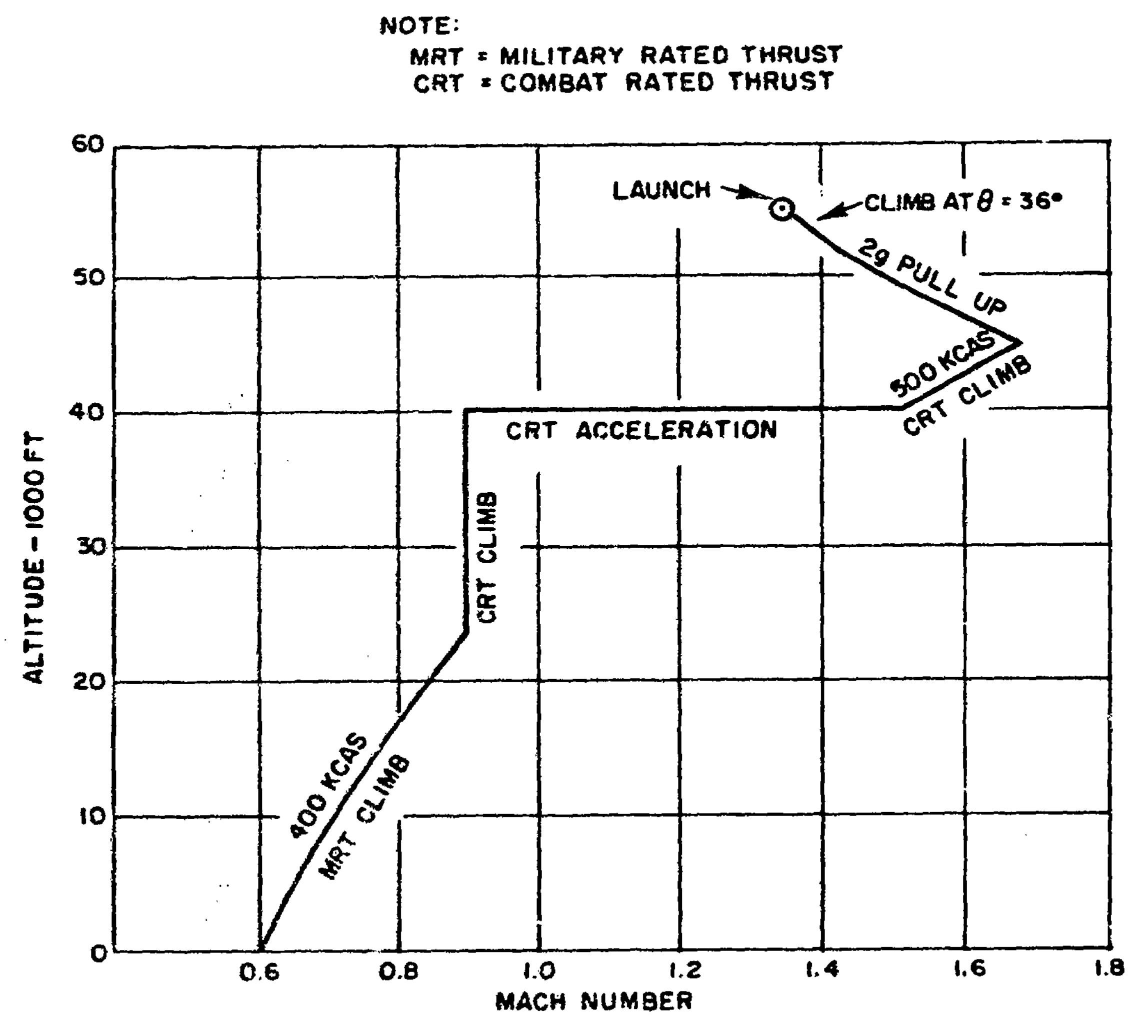

Figure 7
Project FLAME Nominal Climb Profile

Table II

Project FLAME
F-4J/Pedro Recruit Nominal Climb to Launch

OPERATION	GROSS WEIGHT (LB)	FUEL (LB)	DISTANCE (NM)	TIME (MIN)
1. Start Engines, Taxi, Takeoff and Accelerate to 400 KCAS:	48,168			
5 min. SLS NRT		1303	--	5
1 min. SLS CRT		1013	--	1
2. MRT Climb at 400 KCAS to M = .9	45,852	1011	32.0	3.8
3. CRT Climb to 40,000 ft. at M = .9	44,841	798	13.0	1.5
4. CRT Acceleration at 40,000 ft to 500 KCAS	44.043	2606	54.6	4.7
5. CRT Climb at 500 KCAS ro 45,000 ft	41,437	1796	39.8	2.6
6. CRT Pullup at N_z = 2g to θ = 36°	39,641	191	5.0	.34
7. CRT Climb to 55,000 ft at θ = 36°	39,450	30	0.9	.08
TOTALS:		8748 lb.	145.3 nm	19.02 min

Launch Conditions:

M = 1.35
Altitude = 55,000 ft
γ = 30°
N_z = .86
Gross Weight = 39,420 lb.
Fuel Remaining = 4839 lb.

Note:

SLS = Sea Level Static
NRT = Normal Rated Thrust
MRT = Military Rated Thrust
CRT = Combat Rated Thrust
KCAS = Knots Calibrated Airspeed

Missile Imposed Flight Restrictions

Flutter Considerations

Structural dynamics analyses were conducted by MCAIR to assess the potential for flutter and divergence of the Pedro-Recruit rocket mounted on the centerline station of the F-4J airplane. The analyses encompassed all captive flight Mach numbers and took into account the stiffness and mass distribution of the vehicle as well as the stiffness of the launcher. Wind tunnel derived aerodynamic coefficients were used in these analyses. These analyses indicated that neither store flutter nor divergence would occur within the flight envelope. Static load amplification in yaw, which is an increase in aerodynamic load resulting from aerodynamically induced deflection, is estimated to cause not more than a 3% increase over the load that would occur on a rigid launcher/store system.

Flutter and divergence assessment was made in pitch and yaw on the basis of the relative locations of store c.g., elastic axis, and aerodynamic center. The captive vehicle was flutter free in both pitch and yaw for all flight conditions. For all pitch and yaw cases except in the yaw degree of freedom below M = 1.1, the aerodynamic center lay aft of the elastic axis and hence divergence could not occur. For M = 1.1, the calculated divergence dynamic pressure in yaw of q = 5000 psf corresponded to more than twice the maximum captive flight speed. Consequently, based on this analysis, there was no requirement for flight placards due either to flutter or divergence of the captive reentry vehicle. A Ground Vibration Test (GVT) of the Pedro-Recruit installed on the F-4J was conducted at NAVAIRTESTCEN. The values of adapter stiffness and elastic axis location obtained from the GVT verified the divergence analysis. In addition, the GVT results verified that the captive vehicle natural frequencies did not coincide with major airframe structural modes.

Takeoff/Landing Rotation Restrictions

Due to the size of the Pedro-Recruit and its position on the aircraft, particular pilot attention to pitch attitude during takeoff and landing is required to ensure rocket/ground clearance. The specification landing condition (10 fps sink rate/11 degrees nose up pitch attitude) for a 46,000 pound gross weight airplane results in a 0.95 inch ground interference with flat main landing gear tires and struts in lieu of the 6.0 inch minimum clearance as provided for normal fleet operations. It was deemed improbable that these landing parameters would occur simultaneously. From flight test data, it was recommended that takeoffs be conducted approximately 12 knots faster than the normal recommended speed (7 to 8 degrees nose up pitch attitude) to avoid Pedro-Recruit ground contact. Takeoff was accomplished with half flaps and combat rated thrust. The technique for landing was minimum sink rate, full flaps, 8 knots fast, and no flare.

Flying Qualities

The MCAIR aerodynamics analysis showed that in the longitudinal axis the Pedro-Recruit caused an aft movement of the Neutral Point of less than 1% MAC subsonically and about 1.2% MAC supersonically. Lateral-directional stability comparisons

of the airplane with and without the Pedro-Recruit were made at Mach numbers of 1.1, 1.3, 1.6, and 2.0. The Pedro-Recruit increased the combined configuration sideforce and rolling moment coefficient curve slopes and had small effect on yawing moment coefficient. The 4 degree nose right installation of the store on the aircraft caused a small shift in the sideforce yawing and rolling moment data at zero sideslip angle. This shift was well within the lateral and directional trim capability of the airplane.

Initial flight testing was conducted on F-4J airplane Bureau Number 153077. Flying qualities tests were conducted at the points shown in figure 8.

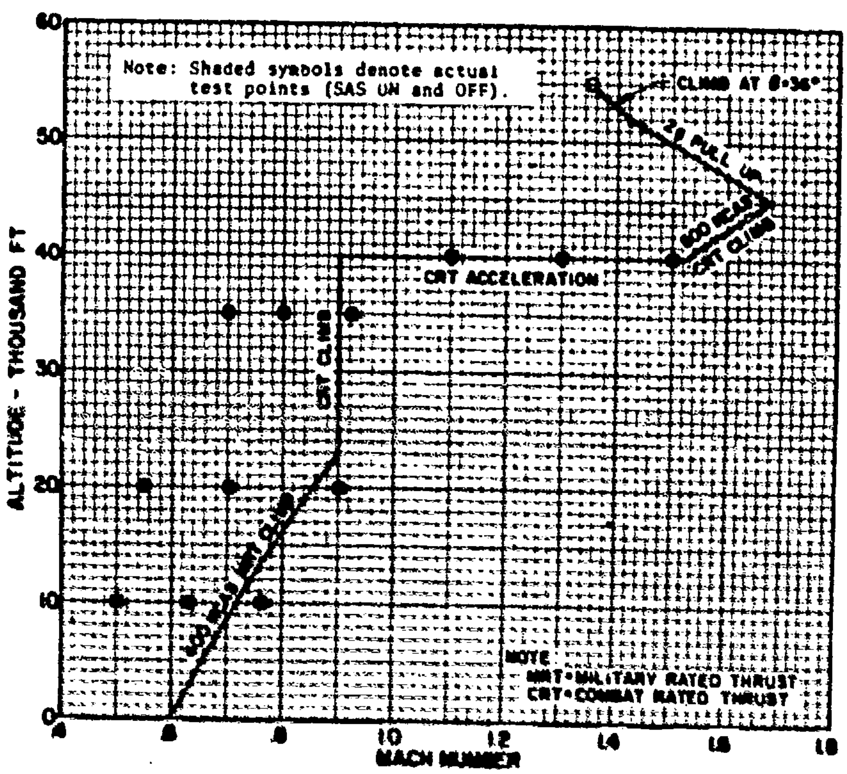

Figure 8
Flying Qualities Test Points

Based on qualitative pilot opinion, the flying qualities were essentially the same as the basic F-4J aircraft with no external stores. Tests were conducted SAS ON and OFF at each of the test conditions. Wind-up turns were limited to 3 g at each test point. A slight amount of rudder trim was required and was considered to be of no significance. The Pedro-Recruit store did not cause aircraft buffet or flutter at any of the conditions tested.

Separation Behavior Analysis

The fact that the release condition programmed for the Pedro-Recruit rocket (Mach 1.35, 55,000 feet, 30° nose up flight path angle) was far outside the normal F-4J release

envelope generated some concern over the possible separation characteristics of the rocket from the airplane. This concern was reinforced by both the unorthodox carriage configuration (4° yaw with respect to the airplane centerline) and the deployable fins on the vehicle. Initial analysis showed that on a standard day the Mach 1.35 release at 55,000 feet corresponded to a 267 knot equivalent airspeed and a dynamic pressure of 242 psf. Based on the low dynamic pressure at the release condition, it was tentatively concluded that aerodynamic effects during separation would not be significant. This conclusion was reinforced by the highly stable characteristics of this store. Data on the vehicle (table III) showed that the center of pressure in the pitch axis was a minimum of 30.29 inches aft of the center of gravity. It was considered that the resulting high stability would tend to keep the store at a low angle of attack and thus minimize the aerodynamic effects on the store separation trajectory even in the presence of perturbations generated by separation transients.

Table III

Pedro/Recruit Aerodynamic Characteristics

<u>M = 1.2</u>	C_{A_0} = .564		$X_{C.G.}$	
CONDITION	C_Y /RAD	$X_{C.P._Y}$ IN.*	C_Z /RAD	$X_{C.P.}$ IN.*
Top fins fully folded	8.12	234.50	-18.14	249.91
Top fins half-deployed	9.70	239.05	-16.55	248.71
Top fins fully deployed	12.12	245.15	-13.13	245.15
<u>M = 2.0</u>	C_{A_0} = .795		$X_{C.G.}$ = 214.30 in*	
CONDITION	C_Y /RAD	$X_{C.P._Y}$ IN.*	C_Z /RAD	$X_{C.P._P}$ IN.*
Top fins fully folded	7.41	231.29	-15.17	269.90
Top fins half-deployed	8.64	236.78	-13.95	249.39
Top fins fully deployed	11.29	244.57	-11.29	244.59

The reference area for the above coefficients is 4.5082 sq. ft.

*Measured from the nosetip.

Pedro-Recruit Aerodynamic Characteristics

In order to validate these order of magnitude consideration it was decided to conduct more detailed test and analysis prior to the first actual separation test flight. The lack of an available store separation characteristic prediction program for the F-4J containing flow field data at the FLAME release conditions led to the decision to use the Captive Trajectory System (CTS) at AEDC, Tullahoma, Tennessee. This system is mounted in a 4 foot supersonic continuous flow wind tunnel. A model of the F-4J airplane is mounted to the tunnel and a model of the Pedro-Recruit is mounted on a sting balance. The sting balance is capable of measuring three forces and three moments on the Pedro-Recruit model (normal, side and longitudinal forces, roll, pitch and yaw moments) and is itself mounted on a positioner capable of six Degree of Freedom (DOF) movement. The model was initially placed by the sting positioner in the captive position on the aircraft. Forces and moments were sensed by the sting and input to a hybrid computer which solved the equations of motion for one time increment based on the sensed forces and moments and other external inputs such as launcher ejection characteristics. The sting positioner moved the Pedro-Recruit to the position indicated by solution of these equations and the process was repeated. The time correlated position of the model as it moved through the flow field yielded an estimate of the actual separation characteristics of the Pedro-Recruit from the aircraft.

To assess not only the expected nominal separation characteristics of the Pedro-Recruit but also the sensitivity of these characteristics to changes in the Pedro-Recruit physical characteristics or release condition, a series of tests was made in which each of these parameters was varied about the expected nominal values and the results compared. Variations investigated included:

a. ±5,000 feet variation from the 55,000 foot nominal.

b. Mach Number effects at 1.3 and 1.6 Mach.

c. $\pm 10^{0}$ variation from the 30^{0} nominal flight path release angle.

d. Normal acceleration of 1.5g and 2.0g in addition to the nominal .87g release condition.

e. Ejector force of zero and greater than that expected for the launcher.

f. Store CG variation up to 3 inches aft of nominal.

g. Fins deployed and not deployed.

The model of the Pedro-Recruit used in the AEDC tunnel did not have movable fins to exactly simulate the actual vehicle. However, since the fins are folded at launch, remain folded during the first 500ms of the separation, and since the folded fin presents the maximum C_{z_α} values, a launch with folded fins at the programmed flight condition was used as the nominal case during these tests. The results of two of the test runs are presented in figures 9 and 10. As can be seen from the figures, the AEDC CTS data indicated that the

separation of the Pedro-Recruit from the airplane would be acceptable. In addition, it is interesting to note that when the predicted vertical displacement of the Pedro-Recruit during separation is compared with the expression

$$Z = V_0 t + \frac{1}{2} a t^2$$

where V_0 ejector end of stroke velocity

t time

a normal acceleration of the aircraft

the results are found to be extremely close (figure 11). Since the above expression represents the missile in a ballistic (non-aerodynamic) environment, the hypothesis that aerodynamic effects on the store separation trajectory are small was again justified.

The order of magnitude considerations presented above and the supporting separation trajectory simulation from AEDC provided sufficient confidence in the Pedro-Recruit separation characteristics for NAVAIRTESTCEN to recommend that NAVAIRSYSCOM issue a clearance for the actual flight test. This clearance was subsequently issued and on 9 October 1974 the first successful inert separation test was conducted at the Tonopah Test Range, Nevada. Program constraints resulted in not having sufficient onboard camera coverage to provide an accurate measurement of the actual store separation. However, what film is available, both onboard and chase, indicates that qualitatively the separation is similar to that predicted by the AEDC tests.

F-4J/PEDRO Recruit Separation Trajectory
M = 1.3 55,000 Ft Altitude $\gamma = 30^\circ$

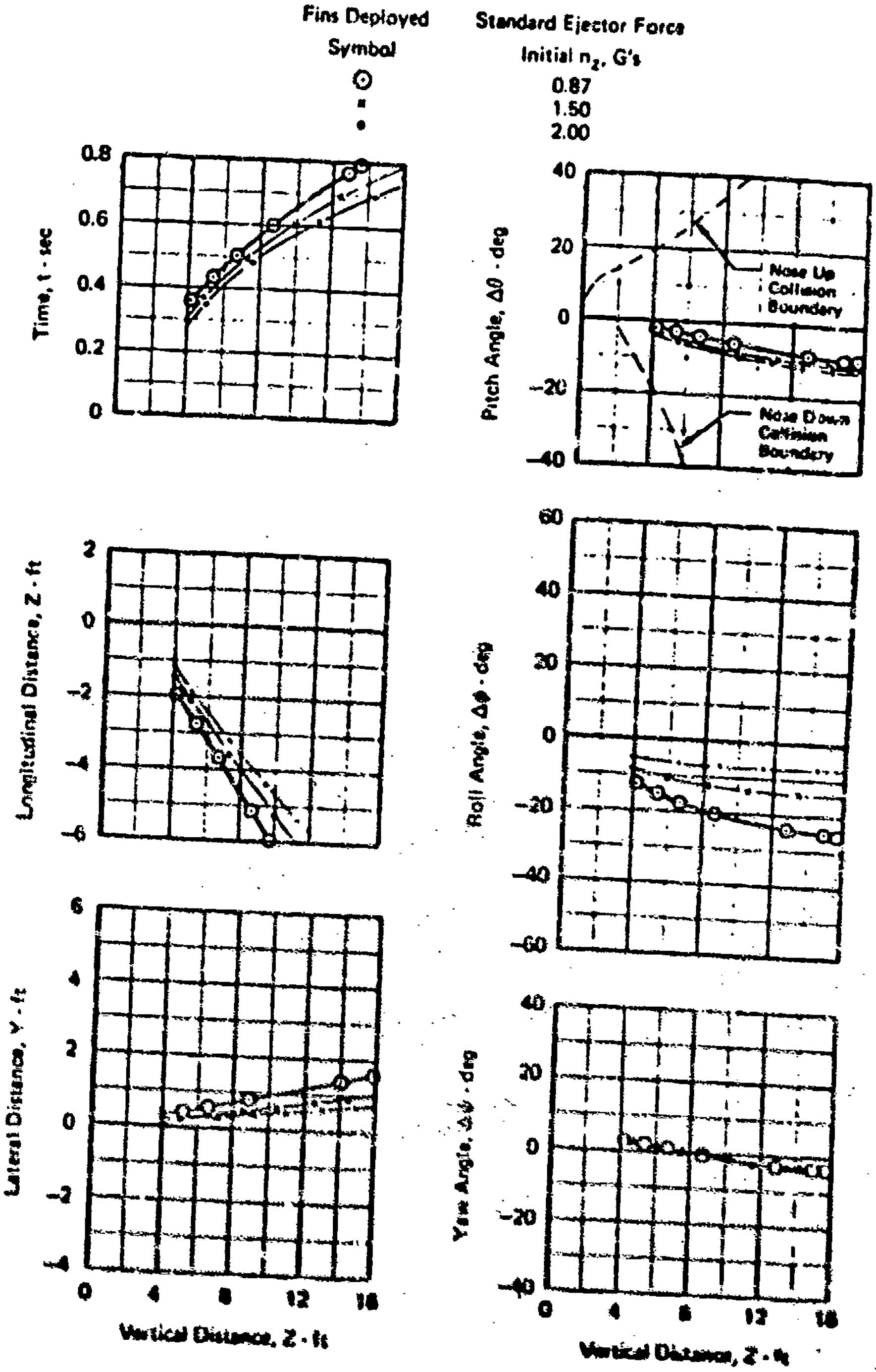

Figure 9
Predicted Separation Trajectories
Standard Ejector Force

PROJECT FLAME

F-4J/PEDRO Recruit Separation Trajectory

M = 1.3   55,000 Ft Altitude   30° Flight Path Angle (γ)

Fins Undeployed   Zero Ejector Force

Symbol	Initial n_z, G's
⊙	0.87
×	1.50
•	2.00

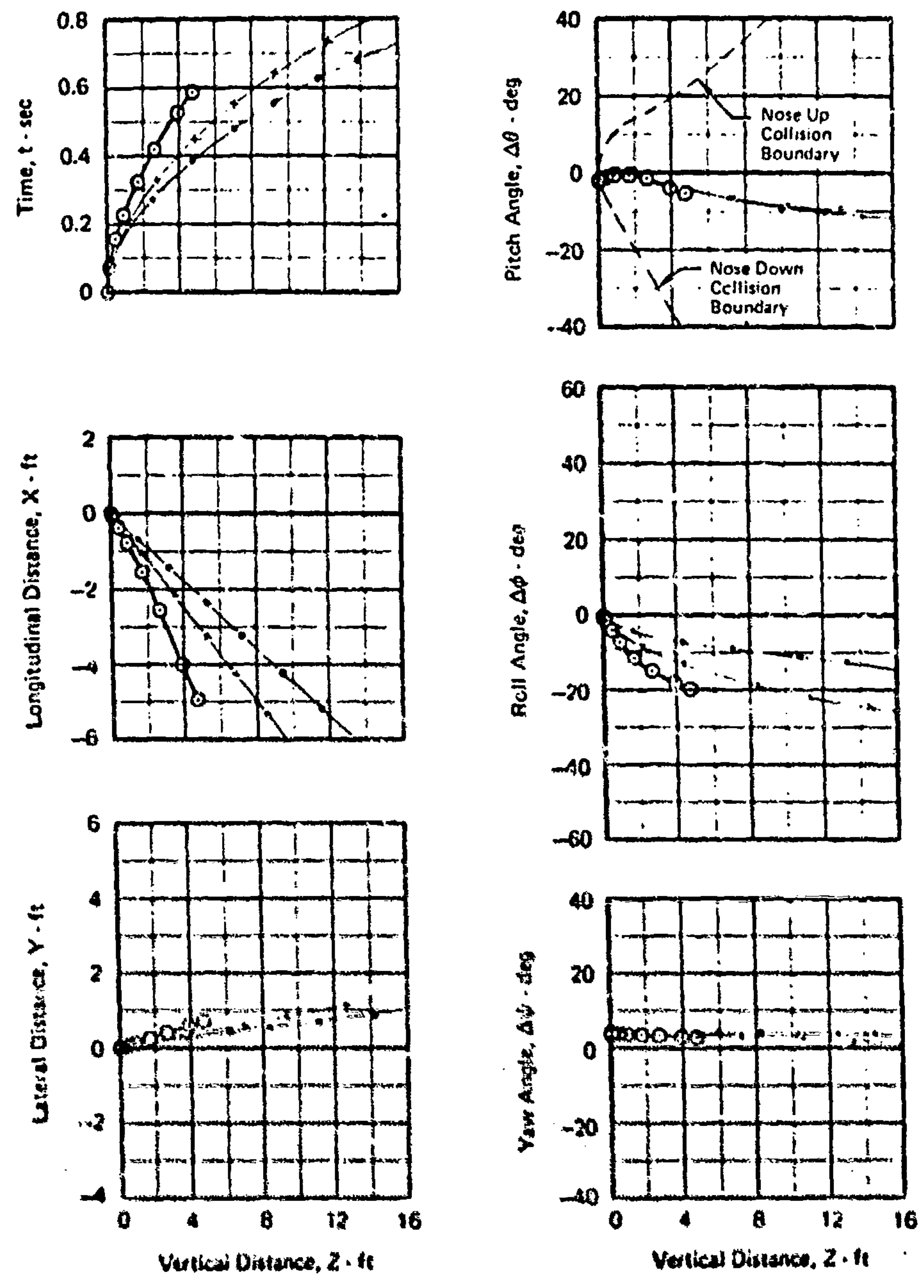

Figure 10
Predicted Separation Trajectories
Zero Ejection Force

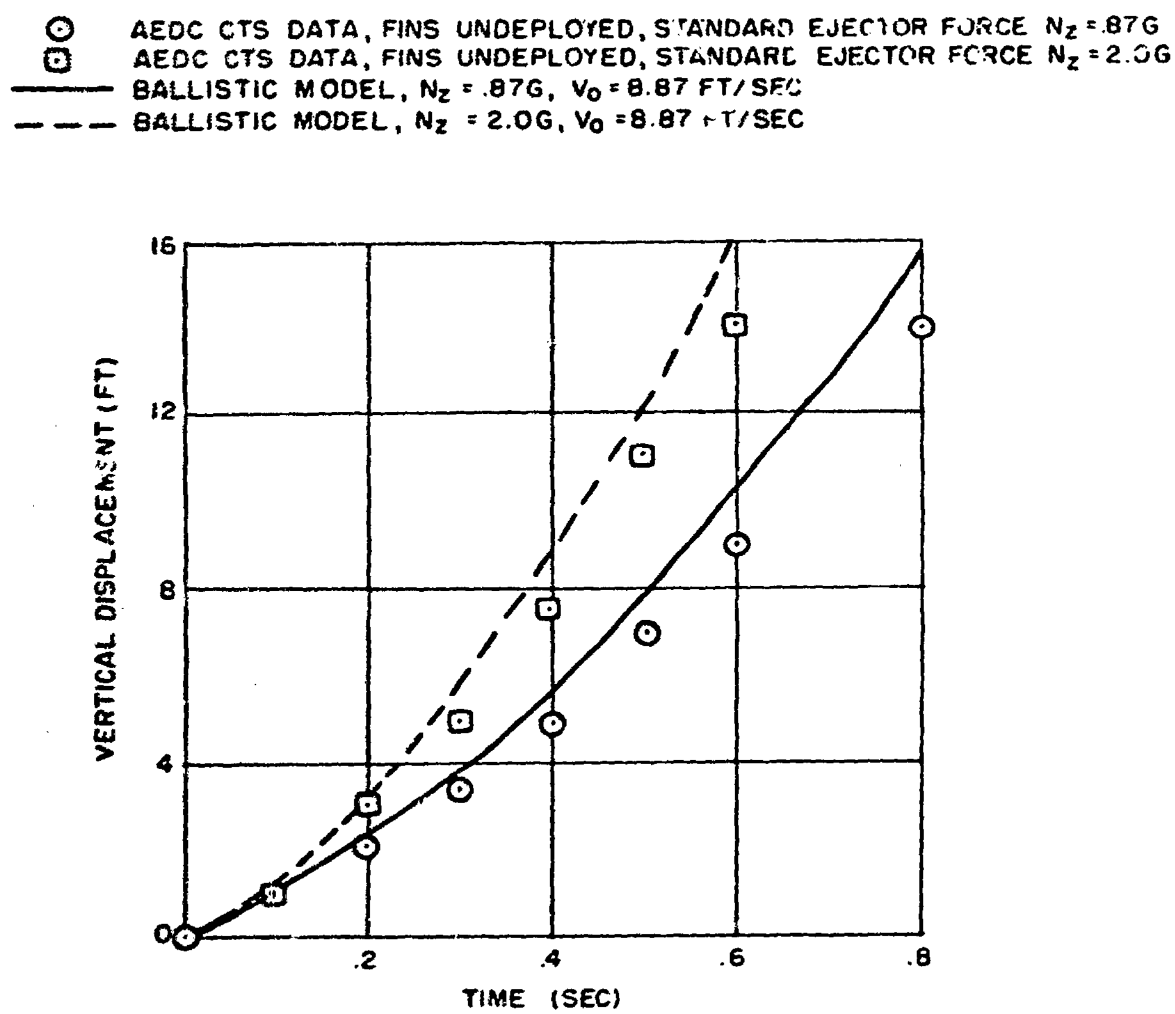

Figure 11A
Ballistic Model/Separation Prediction Comparison

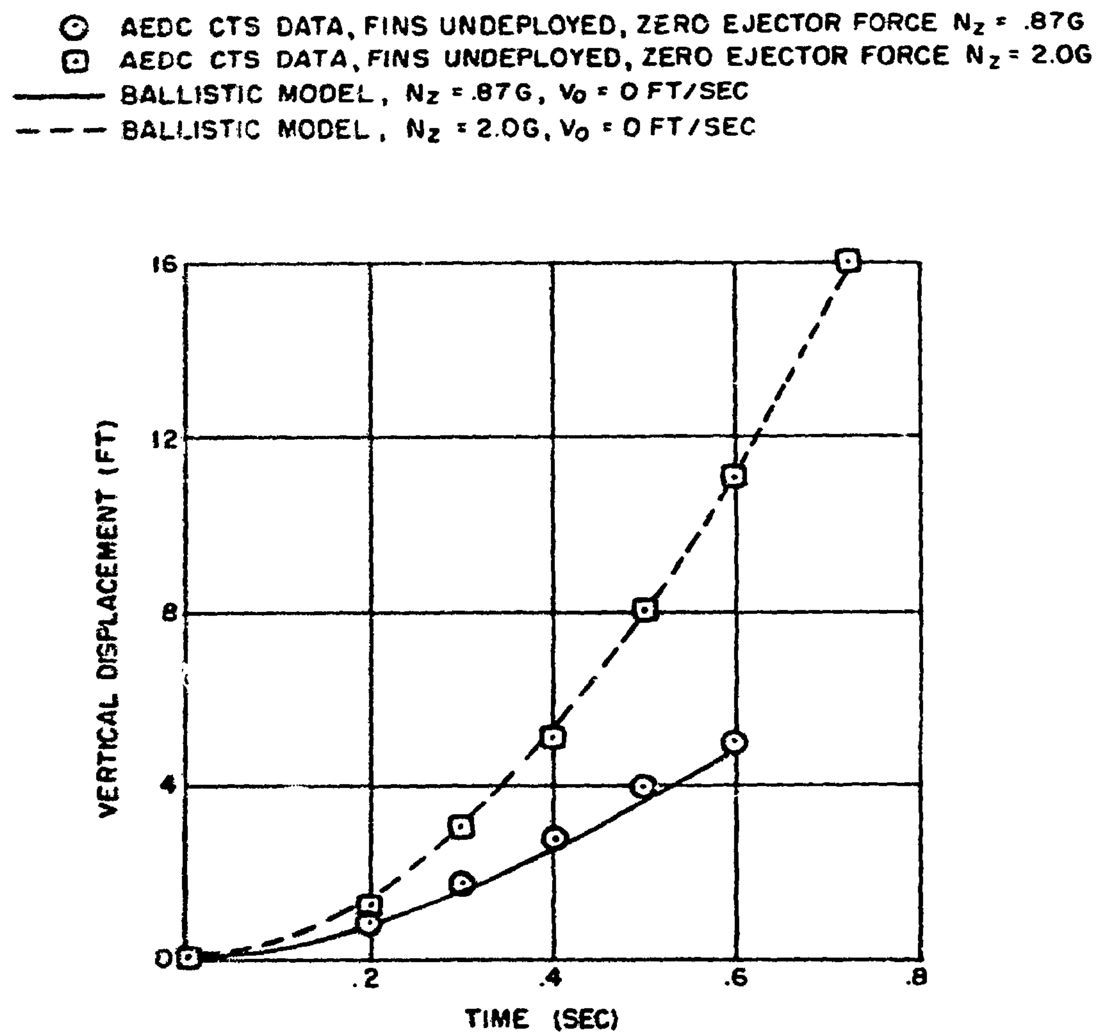

Figure 118
Ballistic Model/Separation Prediction Comparison

IMPLEMENTATION OF CONCEPT

Following the successful separation of the inert Pedro-Recruit on 9 October 1974, six live rockets were successfully released during the period 4 February 1975 to 4 June 1975. Release Mach Number/Calibrated Airspeed varied between 1.224/263 KCAS and 1.366/323 KCAS. Release altitude varied between 54,596 feet and 56,031 feet while flight path angle varied between 30 and 33 degrees nose up. There was no discernible qualitative effect on separation due to these variations. This verified the relative aerodynamic insensitivity predicted by analysis.

The nominal flight profile required a run-in distance of approximately 100 miles from the start of the maximum afterburner acceleration run from 0.9 Mach number at 40,000 ft to the release condition of 1.35 Mach number at 55,000 ft. The time for the acceleration to release was approximately 7.8 minutes. A 2g zoom climb maneuver was utilized at the maximum energy point (1.68 Mach number at 45,000 ft) to attain the nominal release point. Rate of climb at release was approximately 30,000 ft per minute. Altimeter lag was determined to be approximately 2.8 seconds at 55,000 ft. After release, the pilot deselected afterburner and initiated a gradual pushover. Due to the momentum remaining in the zoom climb, a peak altitude of about 72,000 ft was obtained after each launch. No engine stalls or flameouts were encountered during the conduct of these tests.

The implementation of the FLAME concept demonstrated the successful use of store separation prediction techniques to safely clear a new store in a portion of the F-4J flight envelope where store separations had not been previously conducted.

AERODYNAMIC CHARACTERISTICS
OF OPEN WEAPON BAYS
ON THE B-1
(U)
(Article UNCLASSIFIED)

by

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Los Angeles, California

ABSTRACT. (U) The effects of open weapon bays and doors on airplane longitudinal and lateral-directional stability are some of the many design parameters required on all aircraft with internal weapon bays. For a large strategic bomber, such as the B-1, with three internal weapon bays and mixed weapon loads dispensed at subsonic and supersonic speeds, the definition of these effects on aircraft stability involves many variables exercised over a wide range.

This paper presents the aerodynamic forces for the forward and middle weapon bays on the B-1 for mach numbers ranging from 0.6 to 2.2. Data are based on wind tunnel tests conducted at the Rockwell International Trisonic Wind Tunnel facility, using an 0.030-scale model. Included are configuration variables such as bays open and closed, with stored AGM-69 (SRAM) and MK-82 SNAKEYE weapons, as well as launchers full and empty. The forces and moments measured on the weapon bay doors are also presented for two separate door settings, one-half and full open. Schlieren photographs are included for supersonic mach numbers, showing shock wave interaction on the open door configurations.

INTRODUCTION

During the period between July and August 1972, trisonic wind tunnel test TWT-265 was conducted at the Rockwell International Trisonic Wind Tunnel. The 0.030-scale B-1 weapon separation model was modified to take a 1-1/2 inch force balance. Aerodynamic forces were measured with the forward and middle weapon bays open, closed, and closed with stub doors. Stored weapon configurations included the SRAM and MK-82 SNAKEYE. A total of 83 blows and 100 hours were used to obtain these data.

Forces and moments were measured on the weapon bay doors in conjunction with the total aerodynamic forces on the model. The weapon bay door loads measured during this test supersede the data collected in earlier tests at AEDC.

This paper summarizes results and analyzes the tests. A complete set of wind tunnel data and detailed analysis are contained in Rockwell report NA-72-1002 (reference 1).

SUMMARY

Six component force and moment coefficients are presented for various weapon bay configurations at mach numbers ranging from 0.6 to 2.2. Left and right door loads, torsion, and bending moment are also presented for the open bay configurations.

It should be noted that the test model differs from the actual air vehicle in several important respects. The outer wing panels and aft fuselage are truncated, and the open nacelles are overexpanded. Consequently, absolute aerodynamic data cannot be compared with tail-off data from representative models. The purpose of this test was to determine the incremental effects of weapon bay doors, open bays, and full and empty launchers.

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LIST OF FIGURES

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LIST OF SYMBOLS

Symbol	Definition
b_D	Bomb bay door width, in.
bw	Reference wingspan, in.
C_D	Drag coefficient positive aft
$C_{F_{D_{L,R}}}$	Force coefficient on left (subscript L) and right (subscript R) bomb bay doors. Positive when tending to close doors.
C_L	Lift coefficient, positive up
C_ℓ	Stability-axis rolling moment coefficient, positive right roll
C_m	Pitching moment coefficient about airplane CG, positive nose up
$C_{M_{D_{L,R}}}$	Coefficient of bending moment about hinge-side edge of left (subscript L) and right (subscript R) bomb bay doors. Positive when doors are being pushed in closing direction.
C_N	Airplane normal-force coefficient, positive up
C_n	Stability-axis yawing moment coefficient, positive nose right.
$Cp_{s_{L,R}}$	Center of pressure in spanwise direction on left (subscript L) and right (subscript R) bomb bay doors, expressed as a fraction of door width, measured from hinge edge of door.
$Cp_{l_{L,R}}$	Center of pressure in lengthwise direction on left (subscript L) and right (subscript R) bomb bay doors, expressed as a fraction of door length, measured from leading edge of door.
$C_{T_{D_{L,R}}}$	Coefficient of torsional moment about leading edge of left (subscript L) and right (subscript R) bomb bay doors. Positive when trailing edge tends to rotate inboard.

Symbol	Definition
$\bar{c}w$	Airplane reference mean aerodynamic chord, in.
C_Y	Airplane side-force coefficient, positive right
$F1_{L,R}$	Load at gage station farthest from hinge edge on left (subscript L) and right (subscript R) bomb bay doors. Positive in closing direction, lb.
$F2_{L,R}$	Load at gage station nearest hinge edge on left (subscript L) and right (subscript R) bomb bay doors. Positive in closing direction, lb.
h	Moment transfer distance, F_1, to hinge edge of bomb bay door, in.
k	Moment transfer distance, F_2, to hinge edge of bomb bay door, in.
L_D	Length of bomb bay door, in.
Mo	Free-stream mach number
q	Free-stream dynamic pressure, psf
R_N	Reynolds number per foot x 10^{-6}
S_D	Bomb bay door plan area, ft^2
Sw	Airplane reference wing area, ft^2
$T_{L,R}$	Torsional moment about torsion gage axis of left (subscript L) and right (subscript R) bomb bay doors. Positive when tending to rotate trailing edge of door inboard, in.-lb
α	Angle of attack, deg, positive nose up
δD	Bomb bay door opening angle, deg, positive open
ψ	Airplane angle of yaw, deg., positive nose right
Λ	Wing LE sweep angle, deg, positive aft

DISCUSSION

OBJECTIVES

The primary objective of this test was to determine the incremental effects on aerodynamic characteristics of the B-1 air vehicle caused by the weapon bay doors open in two positions. Other objectives included isolation of effects due to doors with and without weapon bay cavity simulation. (Initial tests performed on other models were with "stub," or external, mold line doors.) Also sought were the effects of the SRAM launcher configuration full and empty, and door loads and moments for the open bay configuration.

TEST PLAN AND PROCEDURE

To accomplish the stated objectives, the 0.03-scale store separation model was used as the basic vehicle. This model had the required weapons bay geometry and flexibility, and was suitable for testing at Rockwell's Trisonic Wind Tunnel (TWT) facility. This model had truncated outer wing panels and aft fuselage, but is representative of the B-1 air vehicle in the area of the forward and mid weapons bays. In order to read air vehicle parameters, it was necessary to install a 1-1/2 inch force balance in the space formed by the aft weapons bay. The doors were equipped with strain gages to measure the door loads and moments.

Figure 1 shows the B-1 general arrangement. Figure 2 shows the 0.030-scale model modifications for this test. Figures 3 and 4 show the model installed in the tunnel. In figure 3, the forward bay doors are positioned at the half-open position, while in figure 4, the forward and mid bay doors are full open, exposing the MK-82 SNAKEYE launchers in the full configuration. The SRAM and MK-82 SNAKEYE launchers are shown in figures 5 and 6.

Since the normal delivery mode for the SRAM is a single launch with the bay doors in the half-open position, SRAM delivery simulation was conducted separately for the forward and mid bays. The internal geometry was simulated with a SRAM launcher from which the missiles could be removed for testing of the effects of full and empty launchers. Doors were also tested with the weapons bay closed off to show the incremental door alone effects.

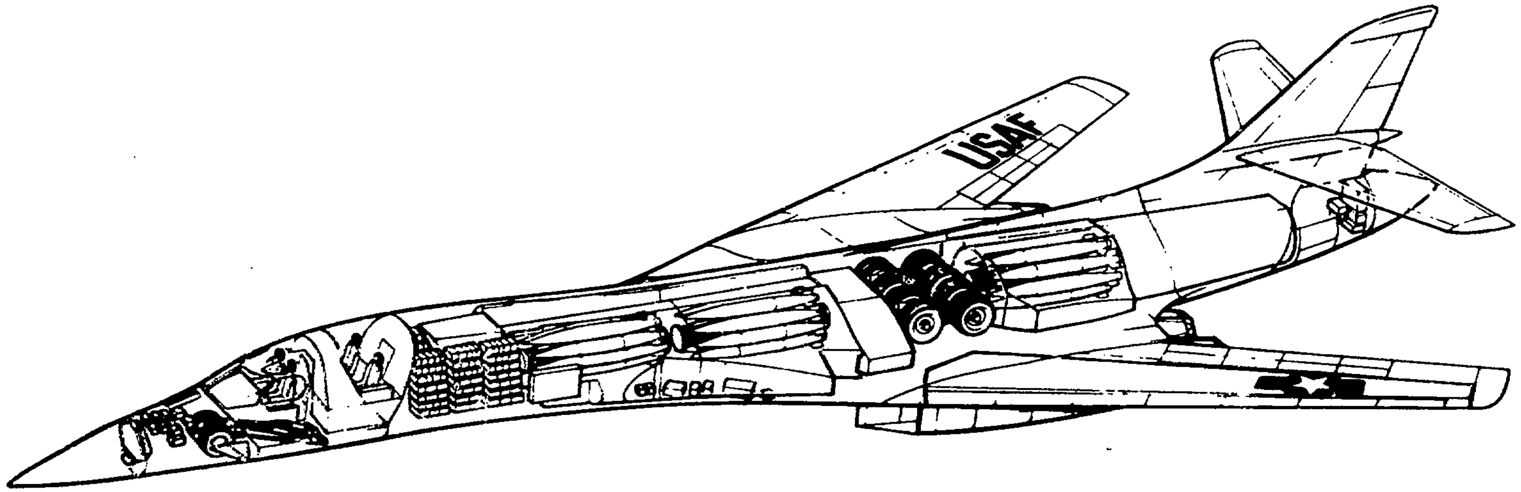


Figure 1. B-1 General Arrangement

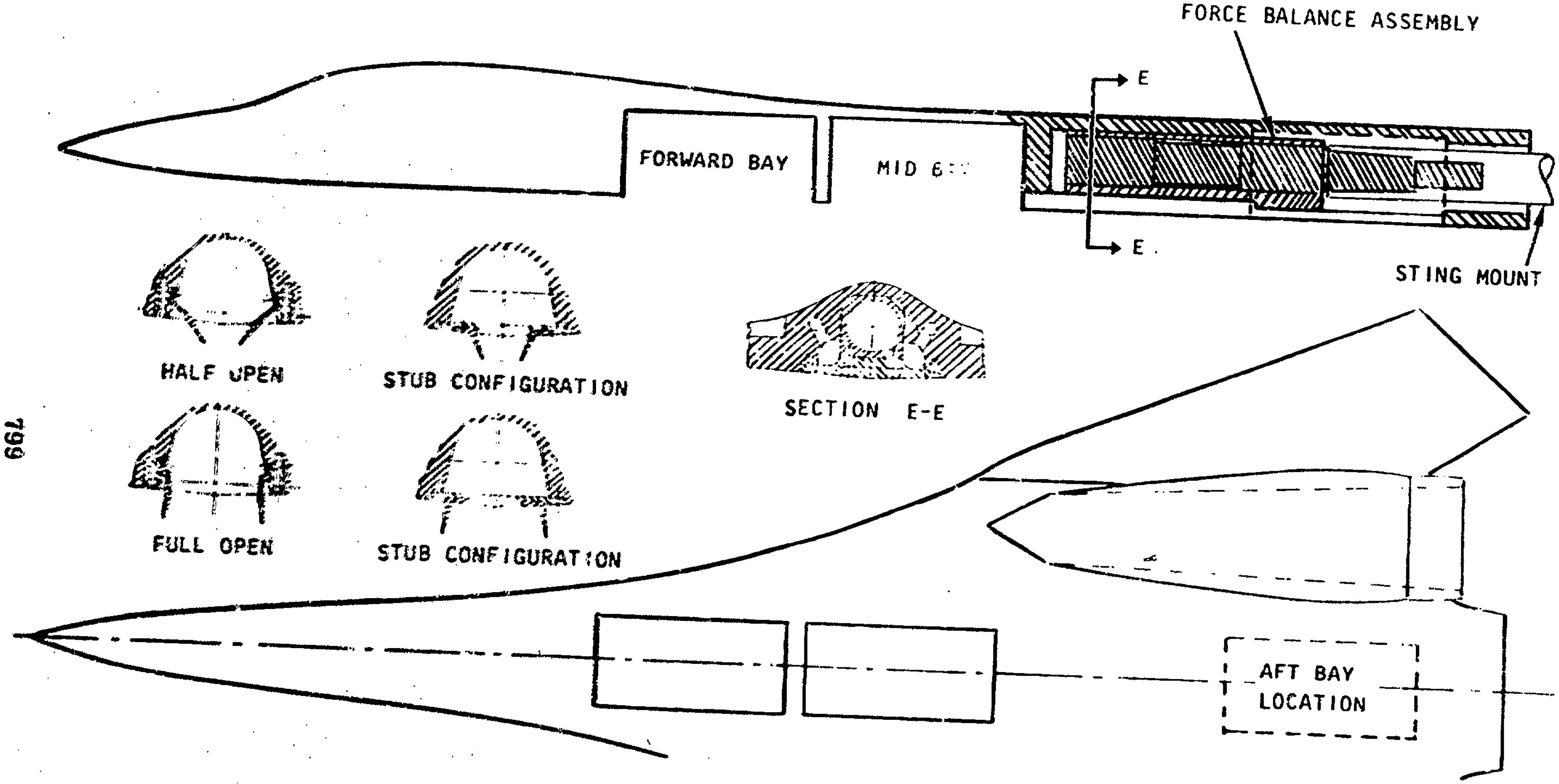
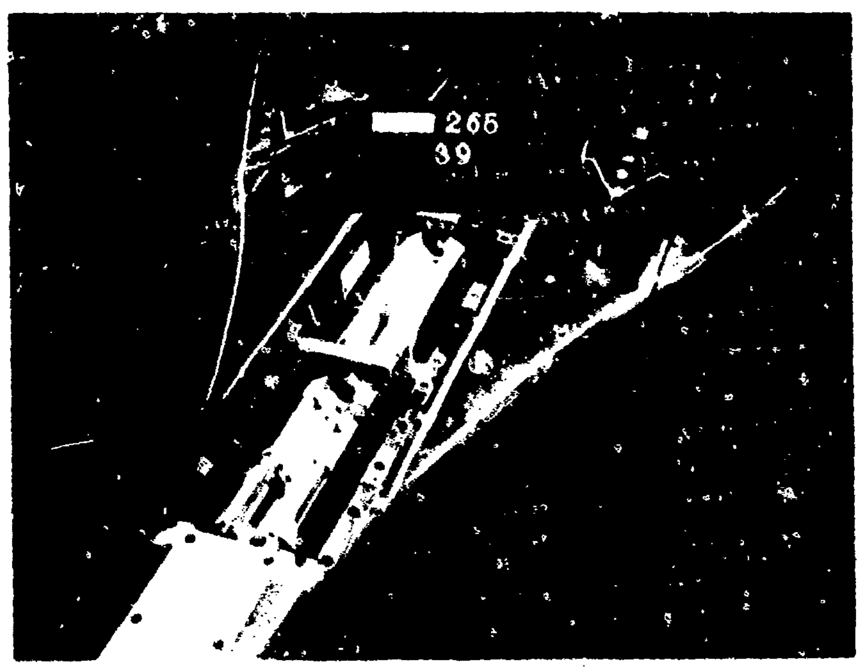


Figure 2. B-1 Store Separation Model, 0.030-Scale

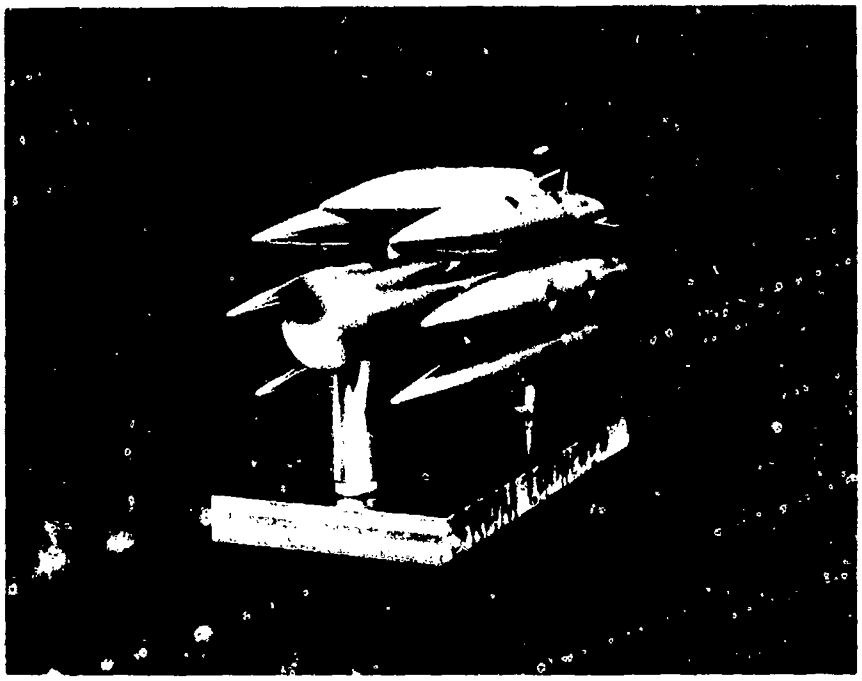
TWT-265-2M

Figure 3. B-1 Model, Tunnel Installation, Forward Bay Doors Half Open



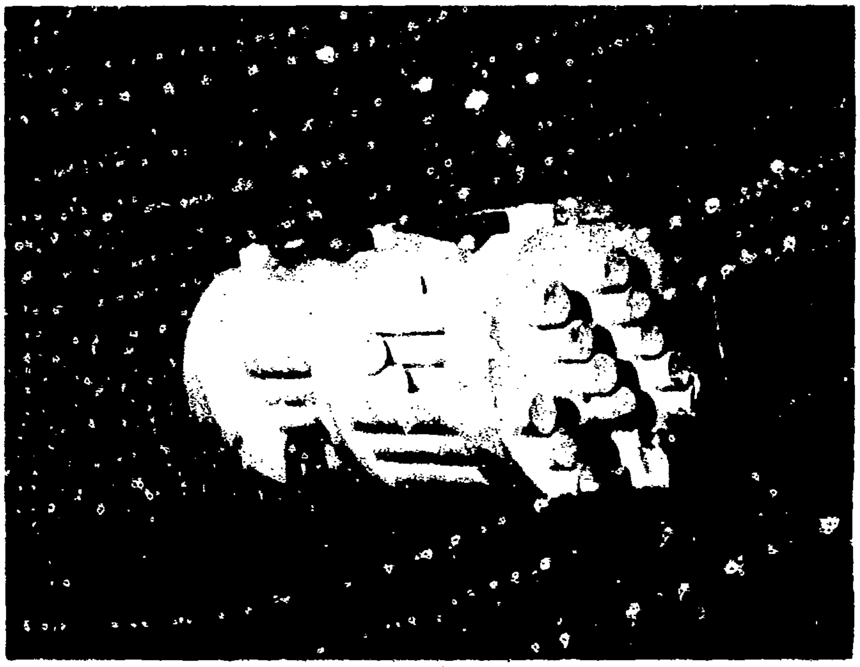
YWT-265-28

Figure 4. B-1 Model, Forward and Mid Bays Full Open, MK-82 SNAKEYE Launchers



TWT-265-2K

Figure 5. AGM-69 SRAM Launcher, 0.030-Scale



TWT-265-2

Figure 6. MK-82 SNAKEYE Launcher, 0.030-Scale

The multiple launch of conventional weapons was simulated by testing the forward and mid bays together with the doors in the fully open position. Simulated MK-82 SNAKEYE launchers were installed in the bays. The conventional weapon investigation was limited to subsonic mach numbers.

This test was conducted at mach 0.6, 0.85, 0.95, 1.2, 1.6, and 2.2. Pitch sweeps of -2 to +10 degrees were run at yaw angles of 0 and 2 degrees for all mach numbers, and at a yaw angle of 5 degrees for mach 0.85 and 2.2. A summary of the test conditions is shown in figure 7.

DATA REDUCTION

Data reduction methods followed normal TWT procedures and are detailed in reference 2. For all runs, the normal six-component aerodynamic data were read as functions of angle of attack (pitch sweeps).

Reference dimensions used for data reduction are given in table I.

DATA ACCURACY

Using the assumption that the difference in wind-off zeros before and after each blow is representative of data repeatability, 95 percent of all data will repeat within the limits defined in table II.

Table I

DATA REDUCTION - REFERENCE DIMENSIONS

Term	Symbol	Model Scale	Full Scale
Wing area	S_W	1.7514 ft^2	1,946 ft^2
Wingspan	b_W	49.205 in.	137 ft
MAC	$\bar{c}_W$	5.522 in.	15.34 ft
Center of gravity	CG	FS29.636, WP 0.600	FS987.85
Bay door area	S_D	0.05355 ft^2	59.5 ft^2
Bay door width	b_D	1.455 in.	48.5 in.
Bay door length	l_D	5.300 in.	176.7 in.
Mom trans dist	h	0.650 in.	---
Mom trans dist	K	0.275 in.	---

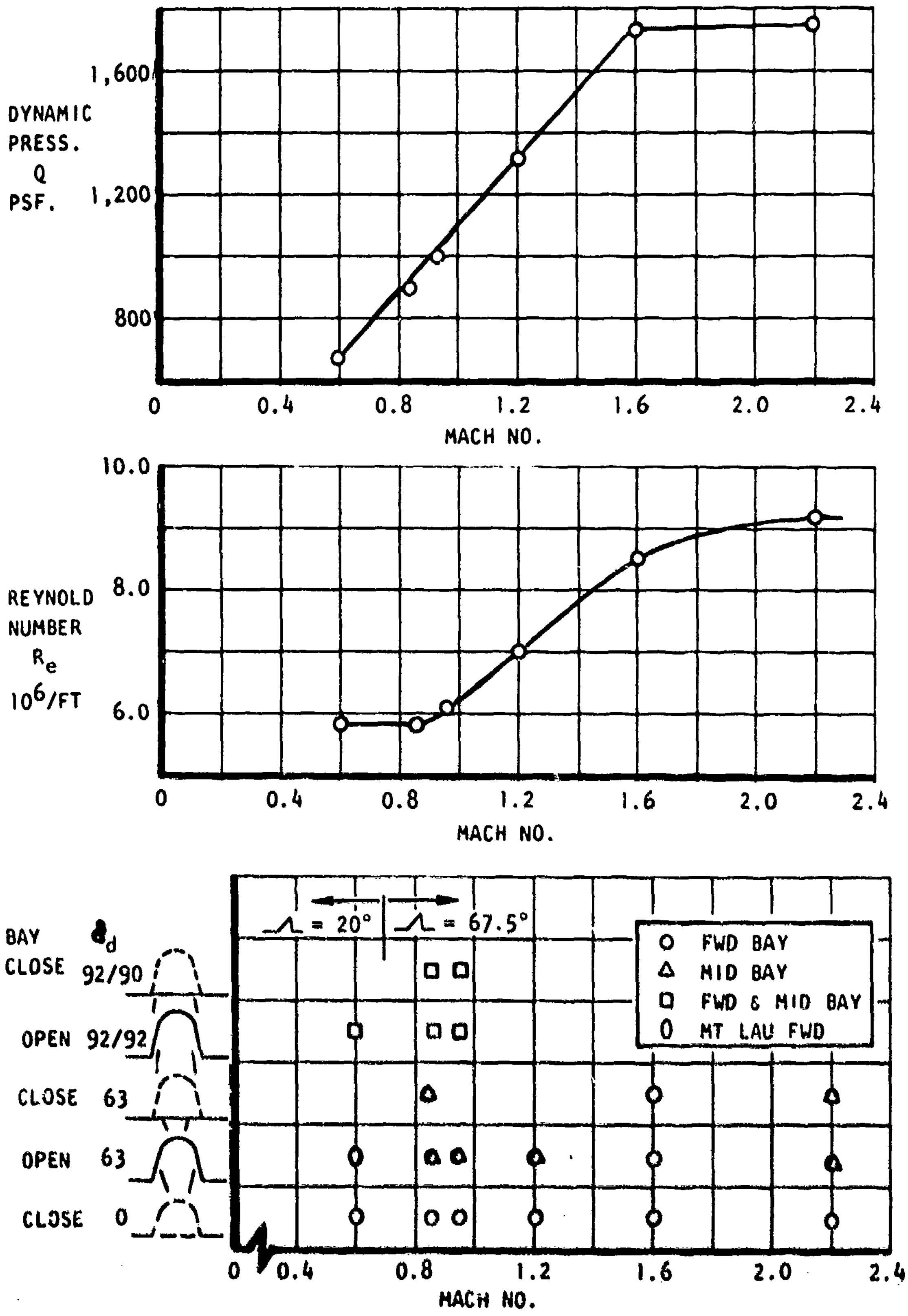


Figure 7. Test Conditions - Summary

Table II

DATA ACCURACY - REPEATABILITY

Term	Symbol	M = 0.85	M = 2.2
Normal force	C_N	0.00096	0.00070
Pitching moment	C_m	0.00046	0.00052
Side force	C_Y	0.00076	0.00060
Yawing moment	C_n	0.00005	0.00006
Rolling moment	C_ℓ	0.00001	0.00002
Bay door force (R)	$C_{F_D}{}^R$	0.0088	0.0081
Bay door force (L)	$C_{F_D}{}^L$	0.0113	0.0076
Bay door torsion (R)	$C_{T_D}{}^R$	0.0013	0.0013
Bay door torsion (L)	$C_{T_D}{}^L$	0.0013	0.0013
Bay door bending (R)	$C_{M_D}{}^R$	0.0045	0.0032
Bay door bending (L)	$C_{M_D}{}^L$	0.0045	0.0034

METHODS AND ANALYSIS

The incremental effects on the air vehicle aerodynamic parameters of the various weapons bay/door configurations are summarized in figures 8 through 16. These incremental effects were determined by subtracting the average values of the clean configuration parameters for an angle-of-attack range between 0 and +5 degrees from like values for the configuration in question. These relationships are:

$$\Delta C_D = C_{D_{OPEN}} - C_{D_{CLEAN}}, \text{ DRAG} \tag{1}$$

$$\Delta C_L = C_{L_{OPEN}} - C_{L_{CLEAN}}, \text{ LIFT} \tag{2}$$

$$\Delta C_M = C_{M_{OPEN}} - C_{M_{CLEAN}}, \text{ PITCH MOMENT} \tag{3}$$

$$\Delta C_Y = C_{Y_{OPEN}} - C_{Y_{CLEAN}}, \text{ SIDE FORCE} \tag{4}$$

$$\Delta C \;\; = C_{n_{OPEN}} - C_{n_{CLEAN}}, \text{ YAW MOMENT} \tag{5}$$

$$\Delta C_{\ell} = C_{\ell\, OPEN} - C_{\ell\, CLEAN}, \text{ ROLL MOMENT} \tag{6}$$

The longitudinal parameters, ΔC_D, ΔC_L, and ΔC_M, are shown as a function of mach number in figures 8, 9 and 10, while the lateral/directional parameters, ΔC_Y, ΔC_n, and ΔC_{ℓ}, are shown for several yaw angles in figures 11 through 15. These data have been averaged over an angle-of-attack range from 0 to +5 degrees.

To determine the incremental stability coefficient of the doors and bays, with respect to side slip angle, the following relationships were used:

$$\Delta C_{n_\beta} = (C_{n\beta})_{OPEN} - (C_{n\beta})_{CLEAN} \tag{7}$$

$$(C_{n\beta})_{OPEN} = \left[\frac{(C_{n_{OPEN}})\,\psi = X - (C_{n_{OPEN}})\,\psi = 0}{\psi = X}\right](-1) \tag{8}$$

NOTE:

$$C_{n\,\beta} = (C_{n\,\psi})\times(-1) \tag{9}$$

$$(C_{n\beta})_{CLEAN} = \left[\frac{(C_{n_{CLEAN}})\,\psi = X - (C_{n_{CLEAN}})\,\psi = 0}{\psi = X}\right](-1) \tag{10}$$

Thus

$$\Delta C_{n_\beta} = \left[\frac{(\Delta C_n)\,\psi = X - (\Delta C_n)\,\psi = 0}{\psi = X}\right](-1) \tag{11}$$

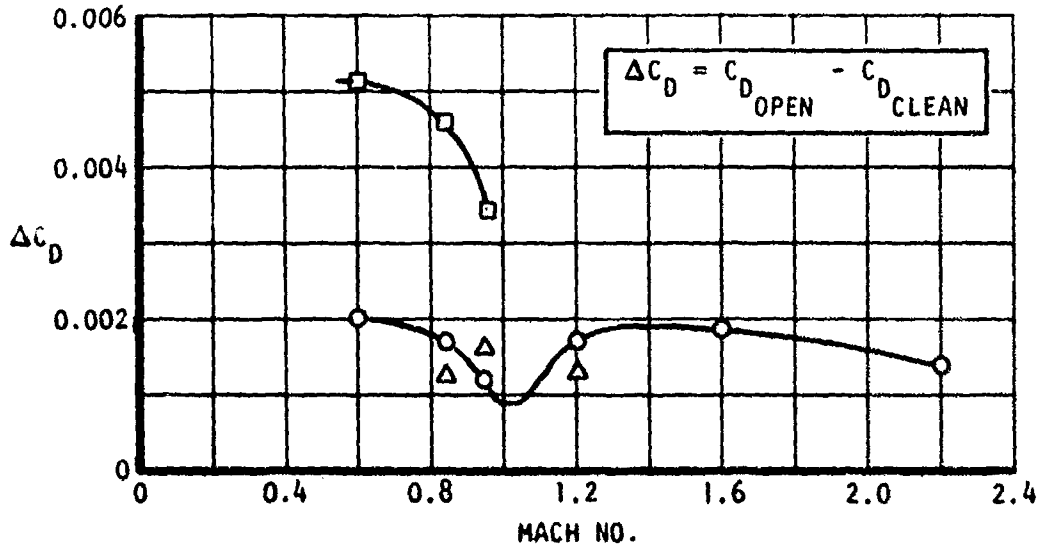
where

$$\Delta C_n = C_{n_{OPEN}} - C_{n_{CLEAN}} \tag{12}$$

NOTE: "OPEN" refers to any selected configuration of open doors or bays, or both.

$S_{REF} = 1,946\ FT^2$
$b_w = 137\ FT$
$c_w = 15.3\ FT$
$CG = FS\ 987.85$
$\alpha = 0° \rightarrow 5°$
$\psi = 0°$

SYM	BAY	LAU	δ_d
○	FWD	FULL	63°
△	MID	FULL	63°
□	FWD + MID	FULL	92°/92°



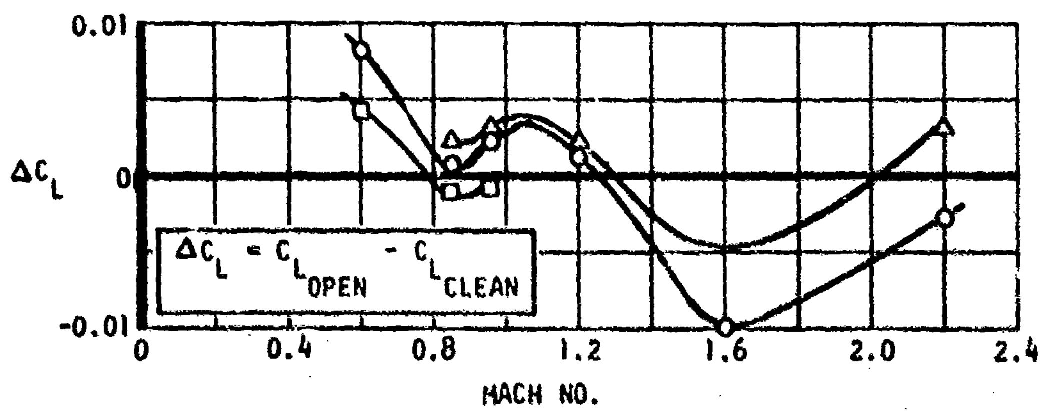


Figure 8. Lift and Drag Due to Open Bays and Full Launcher

$S_{REF} = 1,946\ FT^2$
$b_W = 137\ FT$
$c_W = 15.3\ FT$
$CG = FS\ 987.85$
$\alpha = 0° \rightarrow 5°$
$\psi = 0°$

SYM	BAY	LAU	δ_d
○	FWD	FULL	63°
△	MID	FULL	63°
□	FWD + MID	FULL	92°/92°

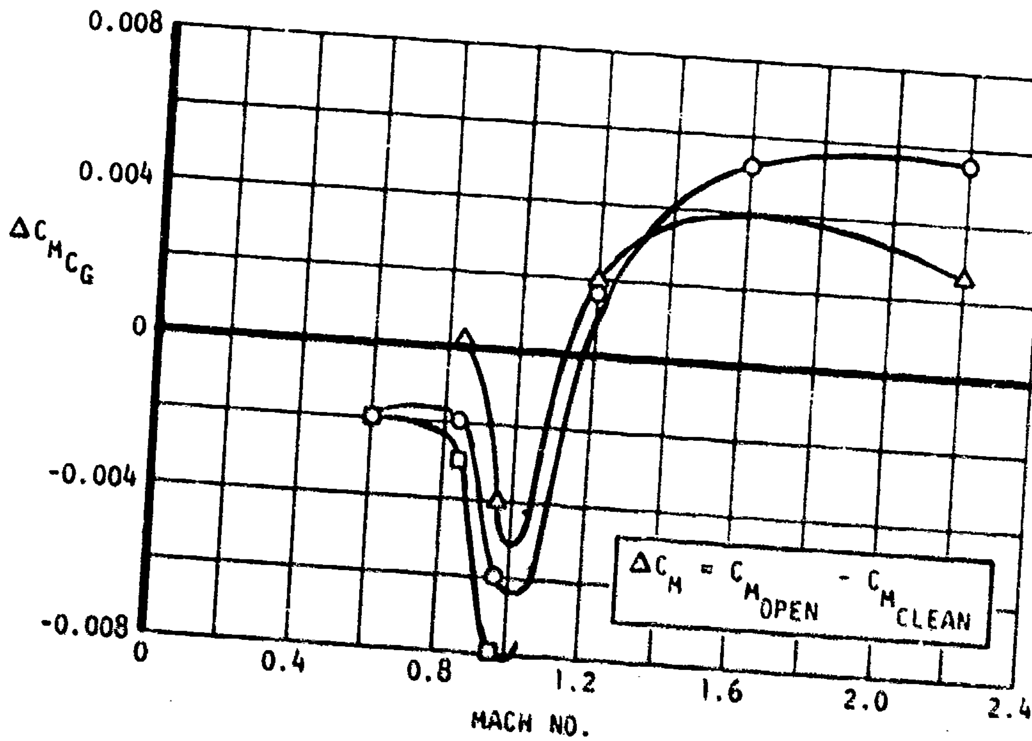


Figure 9. Pitching Moment Due to Open Bays and Full Launcher

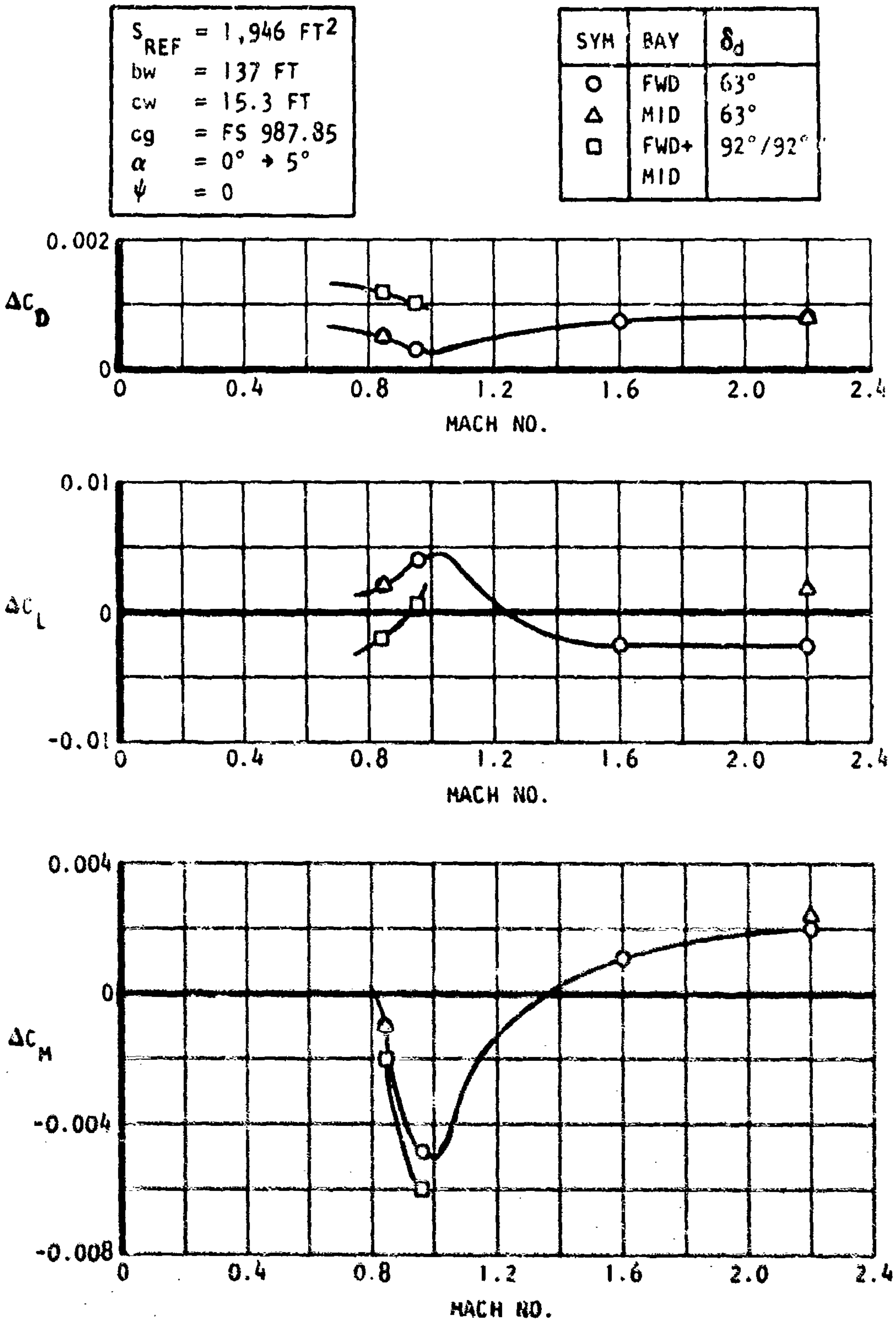


Figure 10. Longitudinal Effects of Closed Bays and "Stub" Doors

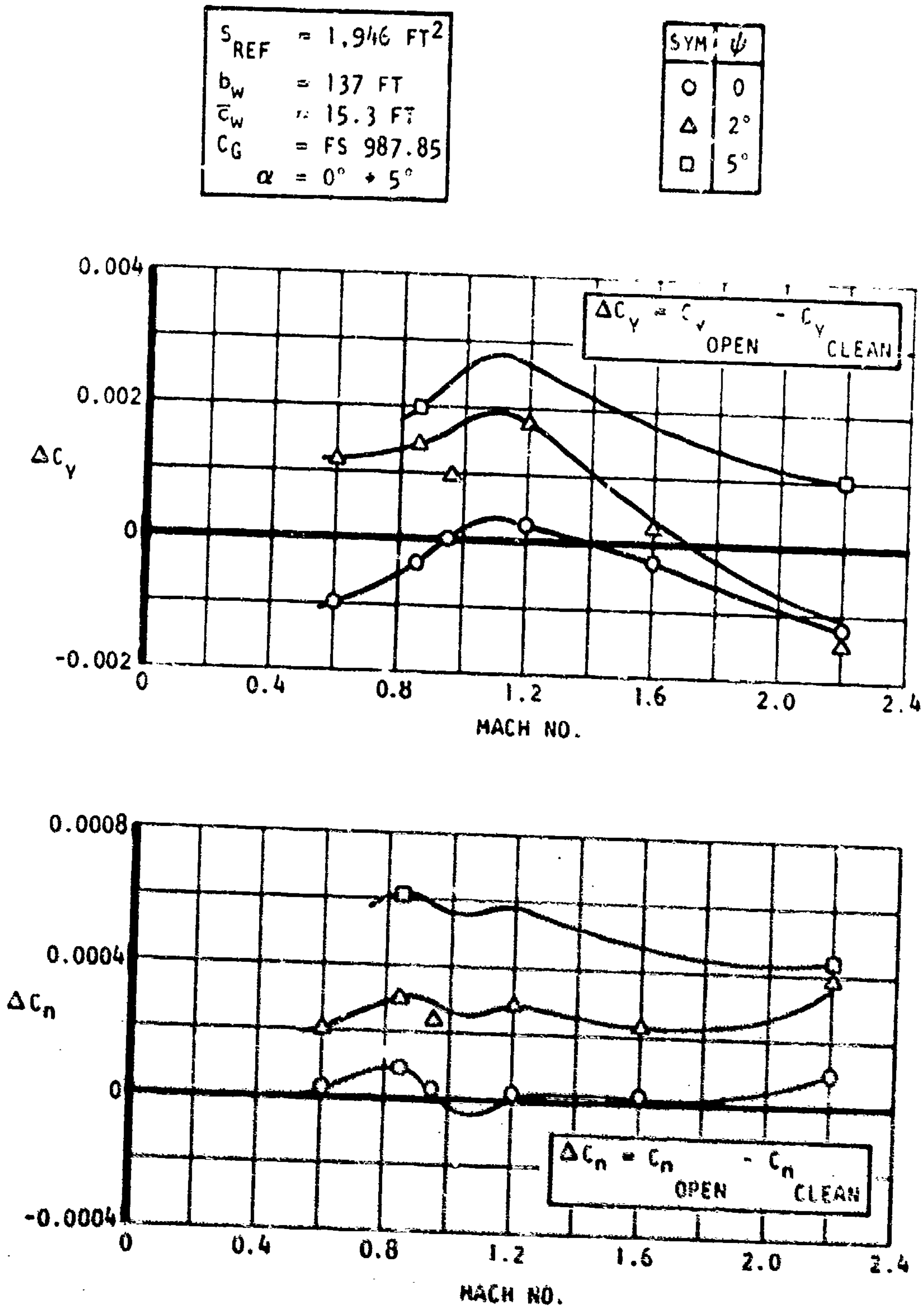


Figure 11. Side Force and Yawing Moment Due to Forward Bay Half Open and Full Launcher

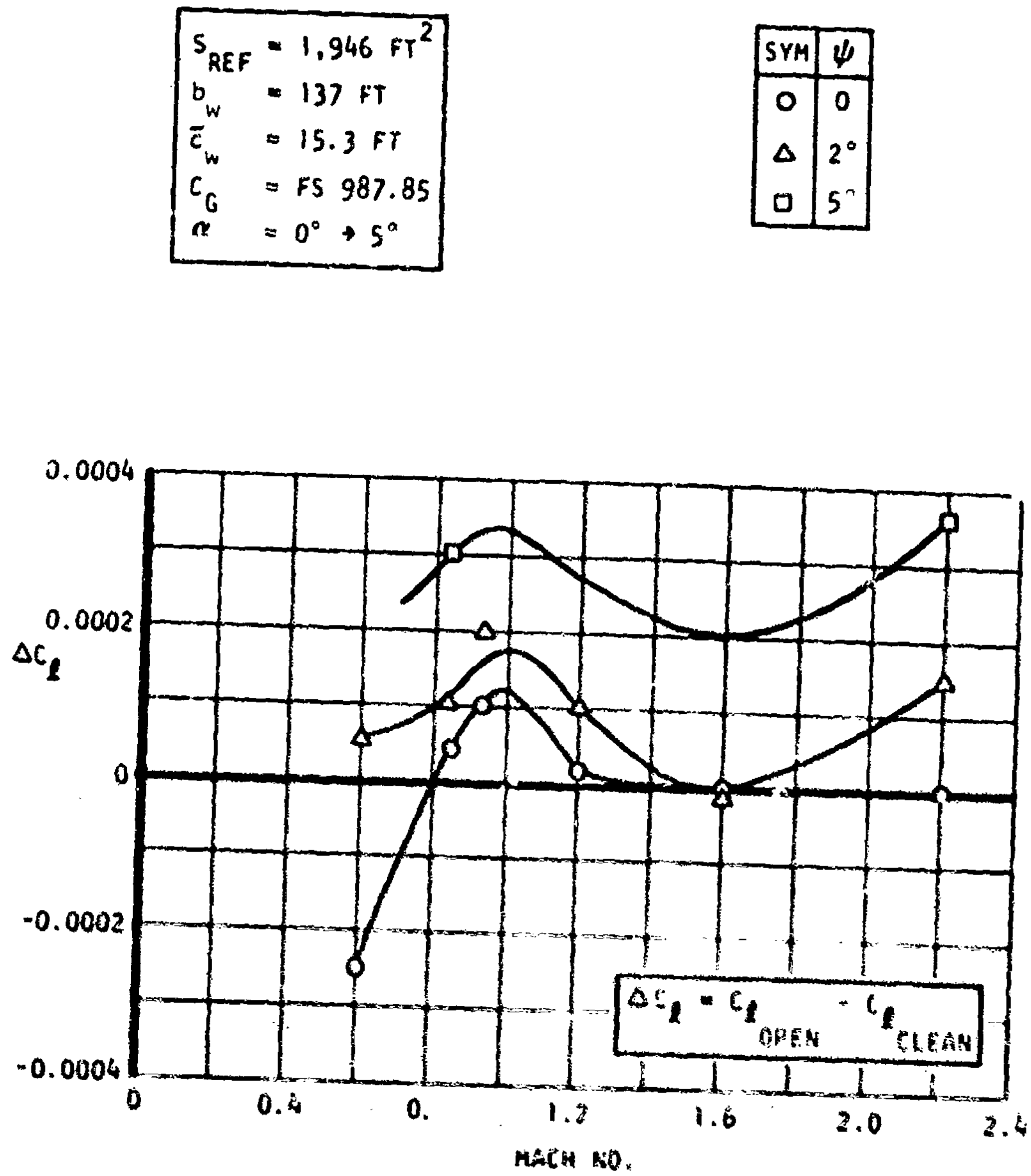


Figure 12. Rolling Moment Due to Forward Bay Half Open and Full Launcher

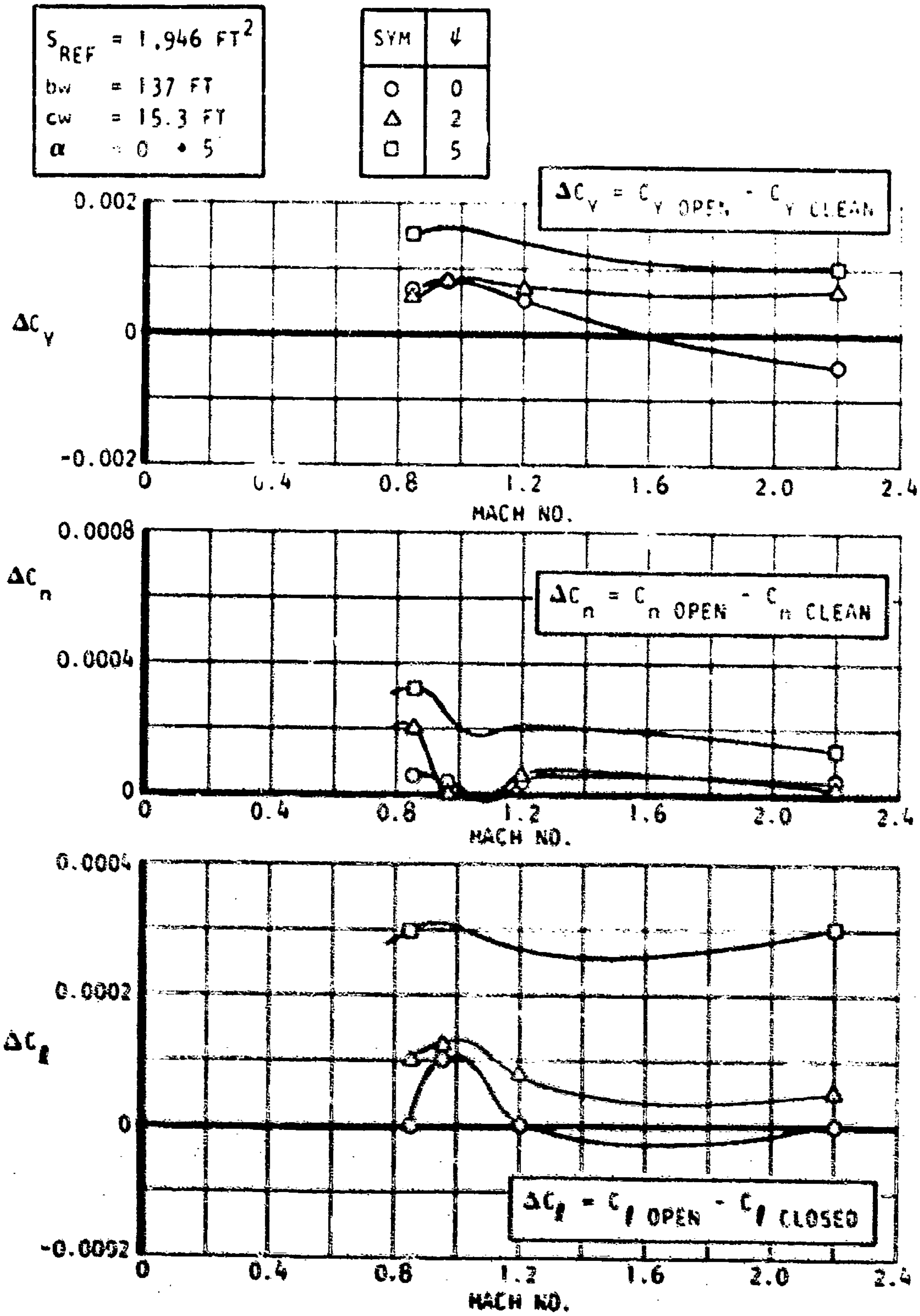


Figure 13. Lateral-Directional Effects of Mid Bay Half Open and Full Launcher

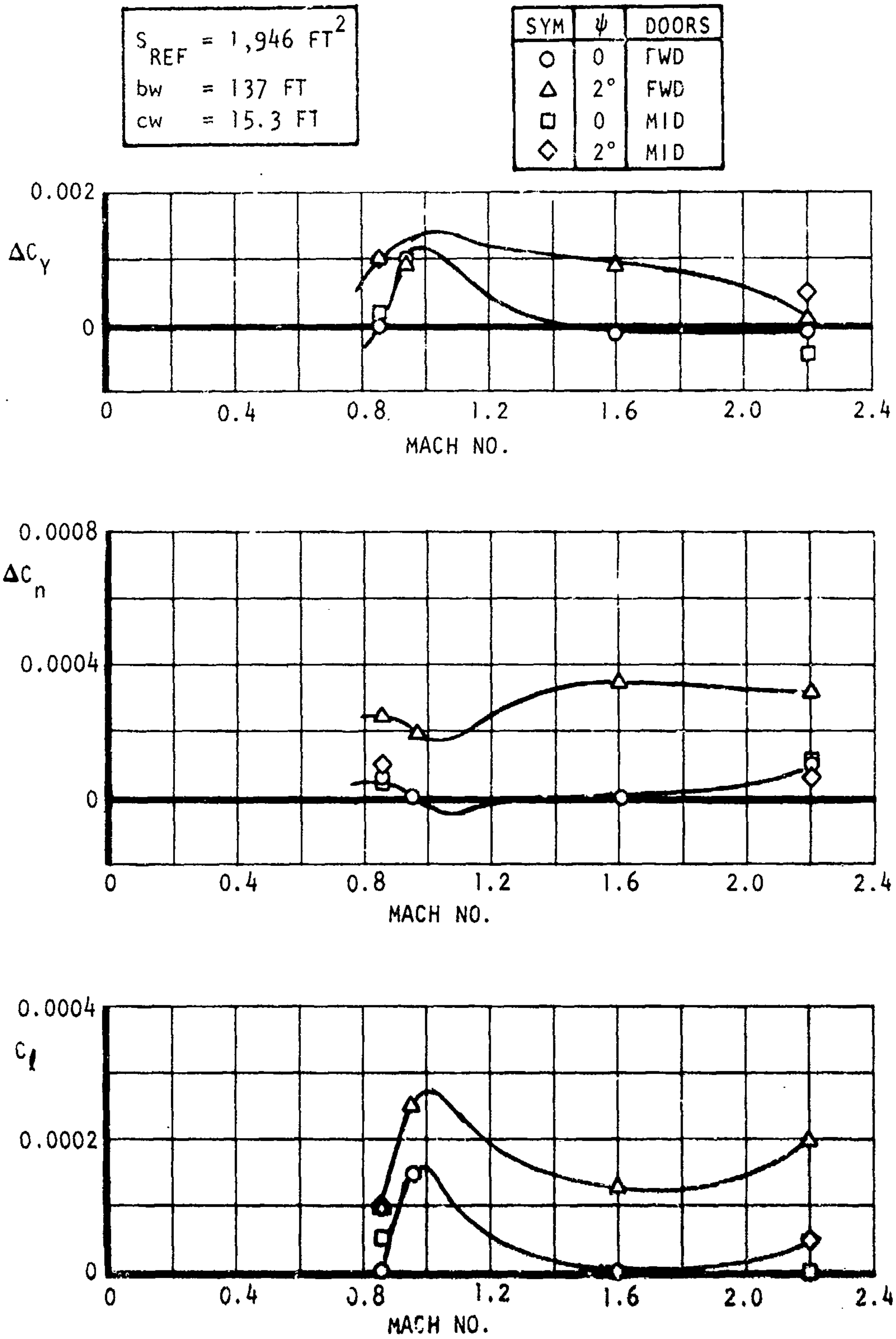


Figure 14. Lateral Directional Effects of Closed Bays and "Stub" Door

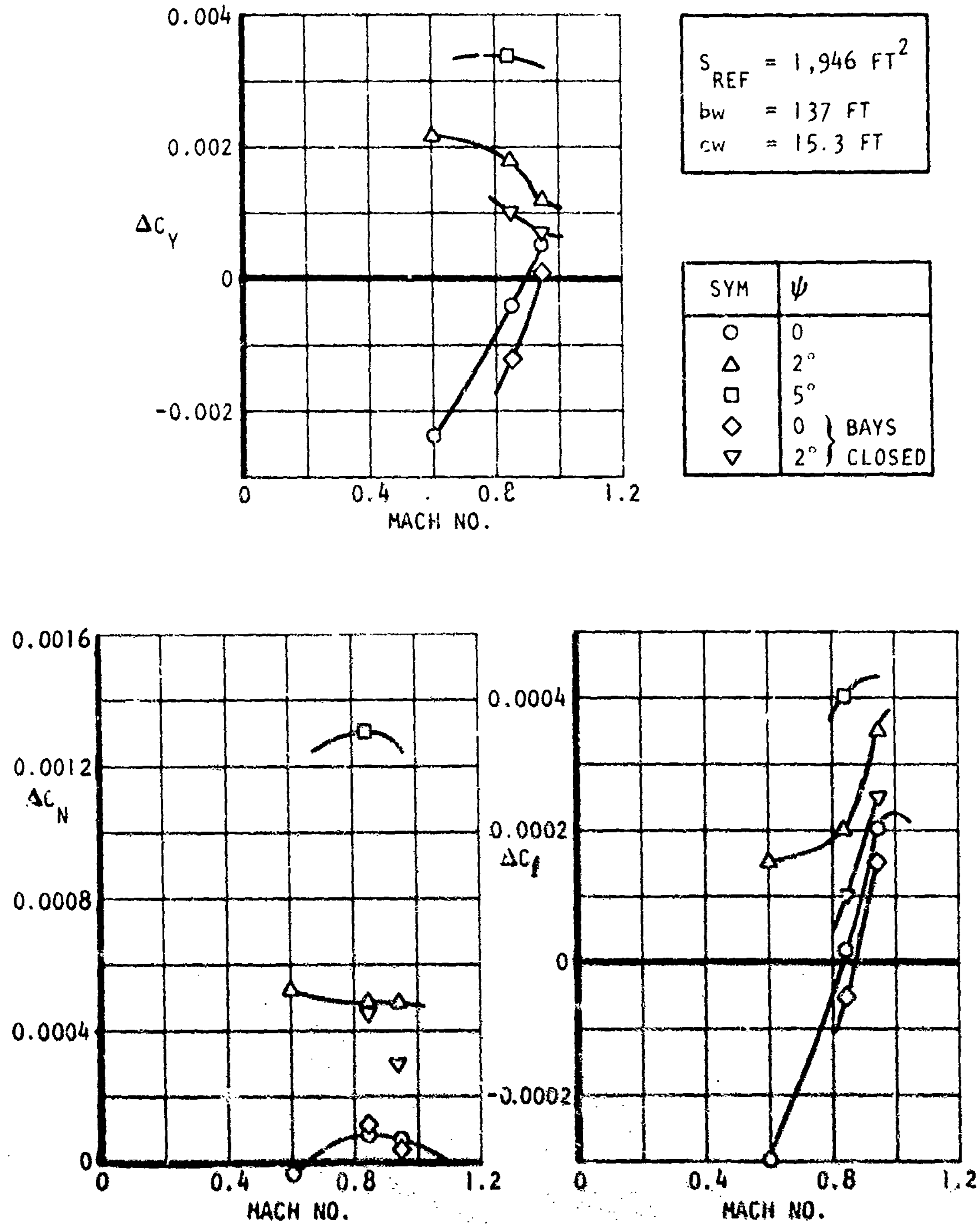


Figure 15. Lateral Directional Effects of Forward and Mid Bay Doors Full Open With Full Launcher and Bays Closed

S_{REF} = 1,946 FT^2
b_w = 137 FT
c_w = 15.3 FT
α = 0° → 5°

BAY OPEN	BAY	LAU	δ_d	BAY	BAY CLOSED
○	FWD	FULL	63°	FWD	+
△	MID	FULL	63°	MID	×
□	FWD + MID	FULL	92°/92°	FWD + MID	λ

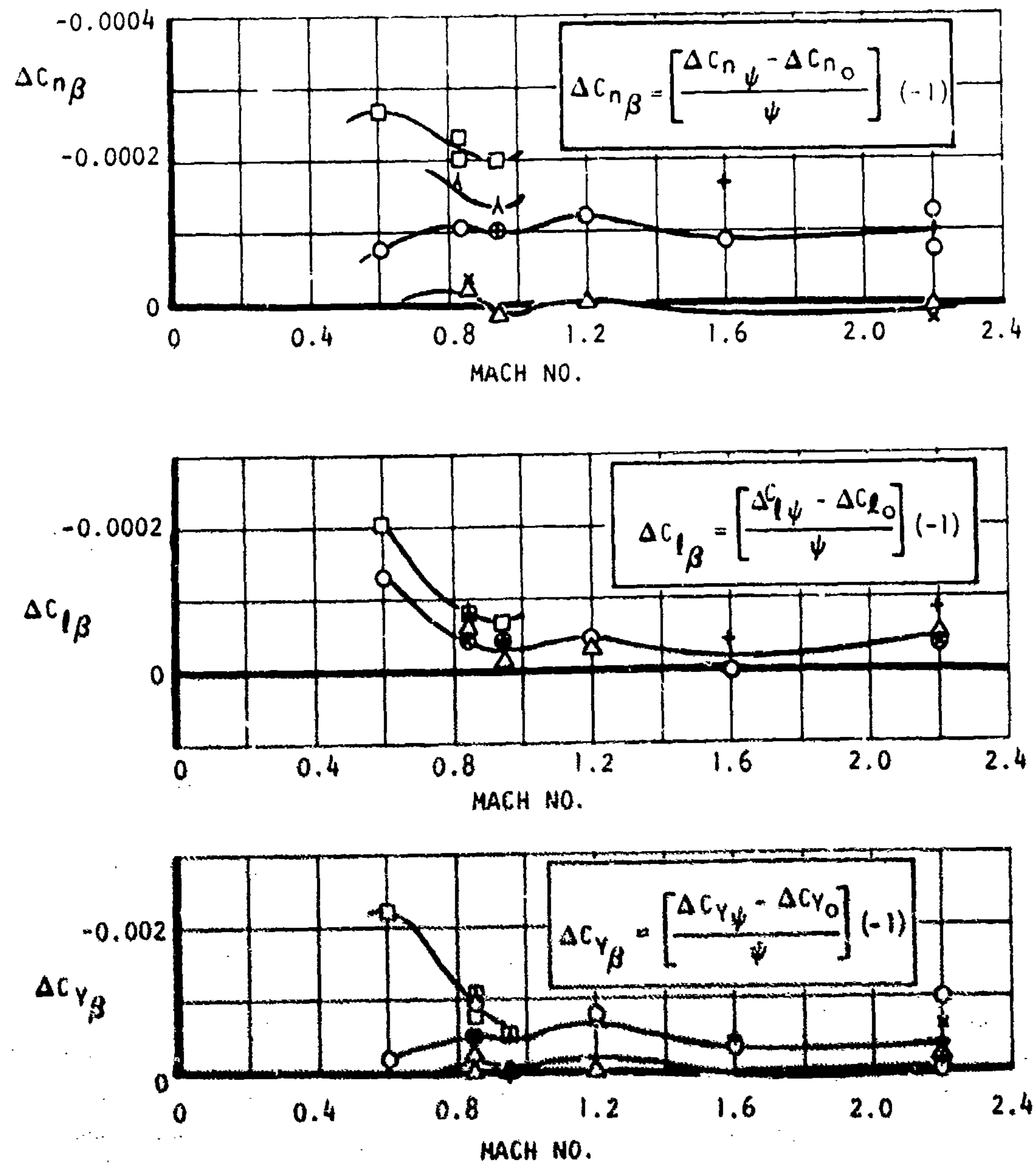


Figure 16. Lateral-Directional Static Stability Effects of Forward and Mid Bay Doors with Bays Open and Closed

Similarly, the roll and side force coefficients were determined:

$$\Delta C_{\ell_\beta} = \left[\frac{(\Delta C_\ell)_{\psi = X} - (\Delta C_\ell)_{\psi = 0}}{\psi = X} \right] (-1) \tag{13}$$

$$\Delta C_\ell = C_{\ell_{OPEN}} - C_{\ell_{CLEAN}} \tag{14}$$

$$\Delta C_{Y_\beta} = \left[\frac{(\Delta C_Y)_{\psi = X} - (\Delta C_Y)_{\psi = 0}}{\psi = X} \right] (-1) \tag{15}$$

where

$$\Delta C_Y = C_{Y_{OPEN}} - C_{Y_{CLEAN}} \tag{16}$$

Plots of ΔC_{n_β}, ΔC_{ℓ_β} and ΔC_{Y_β} appear in figure 16.

The incremental effects due to sideslip were small for all of the configurations tested. When the data accuracy is considered, no distinction in static stability can be made for any of the configurations with bay doors set at 63 degrees. This includes the SRAM launcher empty and full. With both forward and mid bay doors set at 92 degrees, a small difference in C_{n_β} is evident between bay open and closed.

WEAPON BAY DOOR LOADS

A summary of door load data at $\alpha = 0$ is shown in figures 17 through 29 as a function of mach number. Data recorded throughout the angle-of-attack range are shown in reference 1. Consistent results were obtained, well within the data accuracies quoted in table 1. These data supersede weapon bay door load data obtained during earlier testing at AEDC.

The following equations are statements of door loading coefficients and center of pressure. The equations are shown for the left door. Those for the right door are identical, except that subscript "L" is replaced by subscript "R."

$$C_{F_{D_L}} = (F_{1_L} + F_{2_L})/q\, S_D, \text{ FORCE} \tag{17}$$

$$C_{T_{D_L}} = (T_L/q\, S_D\, L_D) + (C_{F_{D_L}}/2), \text{ TORSION (LE)} \tag{18}$$

$$C_{M_{D_L}} = (hF_{1_L} + kF_{2_L})/q\ S_D\ b_D, \text{ MOMENT} \tag{19}$$

$$C_{P_{L_L}} = C_{T_{D_L}}/C_{F_{D_L}}, \text{ CTR PRESS. (LONG.)} \tag{20}$$

$$C_{P_{B_L}} = C_{m_{D_L}}/C_{F_{D_L}}, \text{ CTR PRESS. (SPAN)} \tag{21}$$

Weapon bay door force data are shown in figures 17 through 24. Center-of-pressure data appear in figures 25 through 29. Instrumented doors were used only with the open bay configurations. Door force, torsional moment, and bending moment data are presented for left and right doors to show the effects of yaw at each of the tested mach numbers.

Forward bay data are included for the full SRAM launcher over the full range of mach numbers and for the empty launcher at 0.6 and 2.2. Mid bay doors were not tested at mach 0.6 or 1.6.

With both bays open and the doors full open, the data are shown for the forward doors only.

FLOW FIELD PHOTOGRAPHS

Schlieren photographs of the flow field were taken at mach 1.6 and 2.0. A series of pictures was taken during each angle-of-attack sweep. Figures 30 through 33 are a sampling, showing each configuration with bays open and closed.

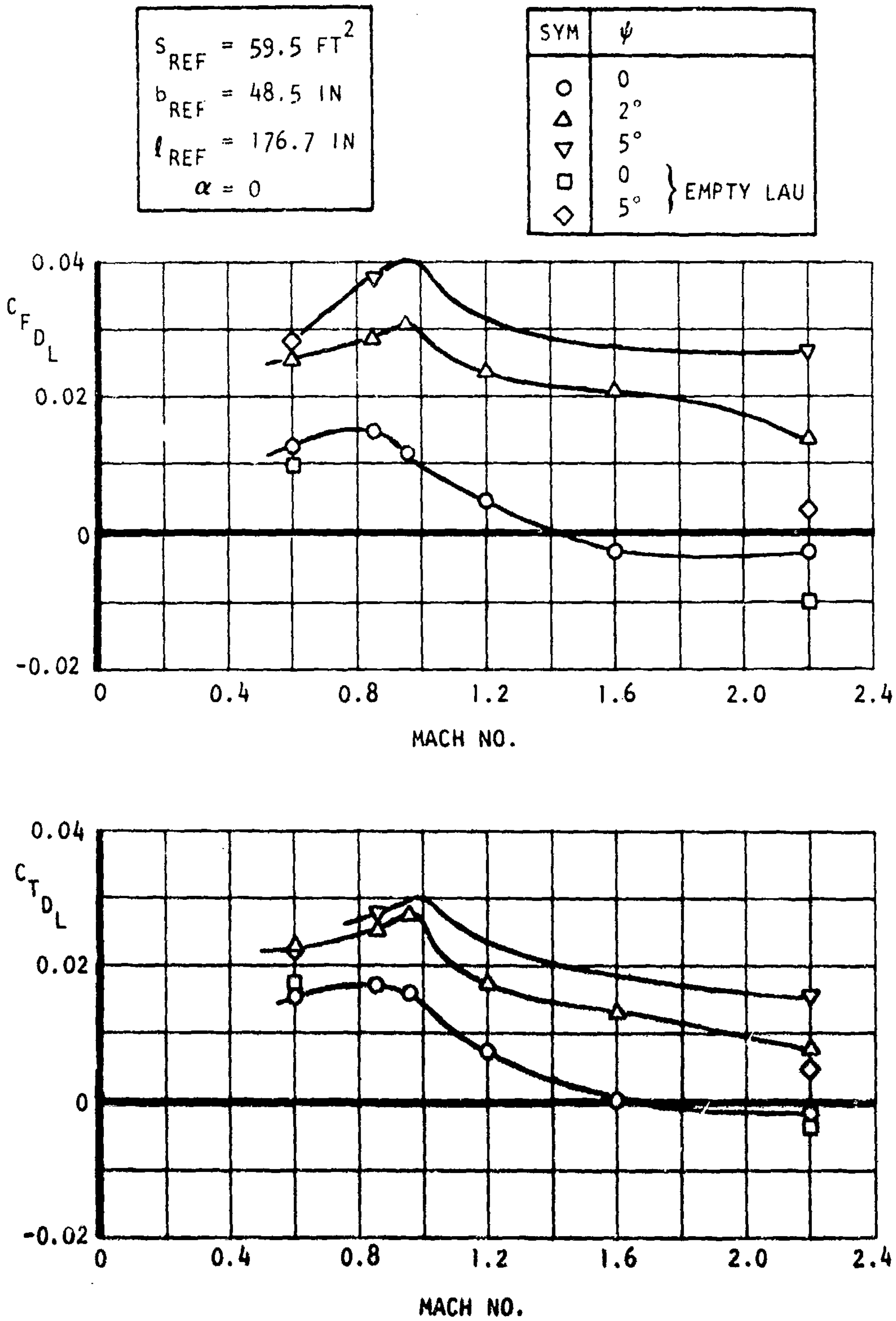


Figure 17. Forward Weapon Bay Door Loads, Force and Torsion Left Door Half Open

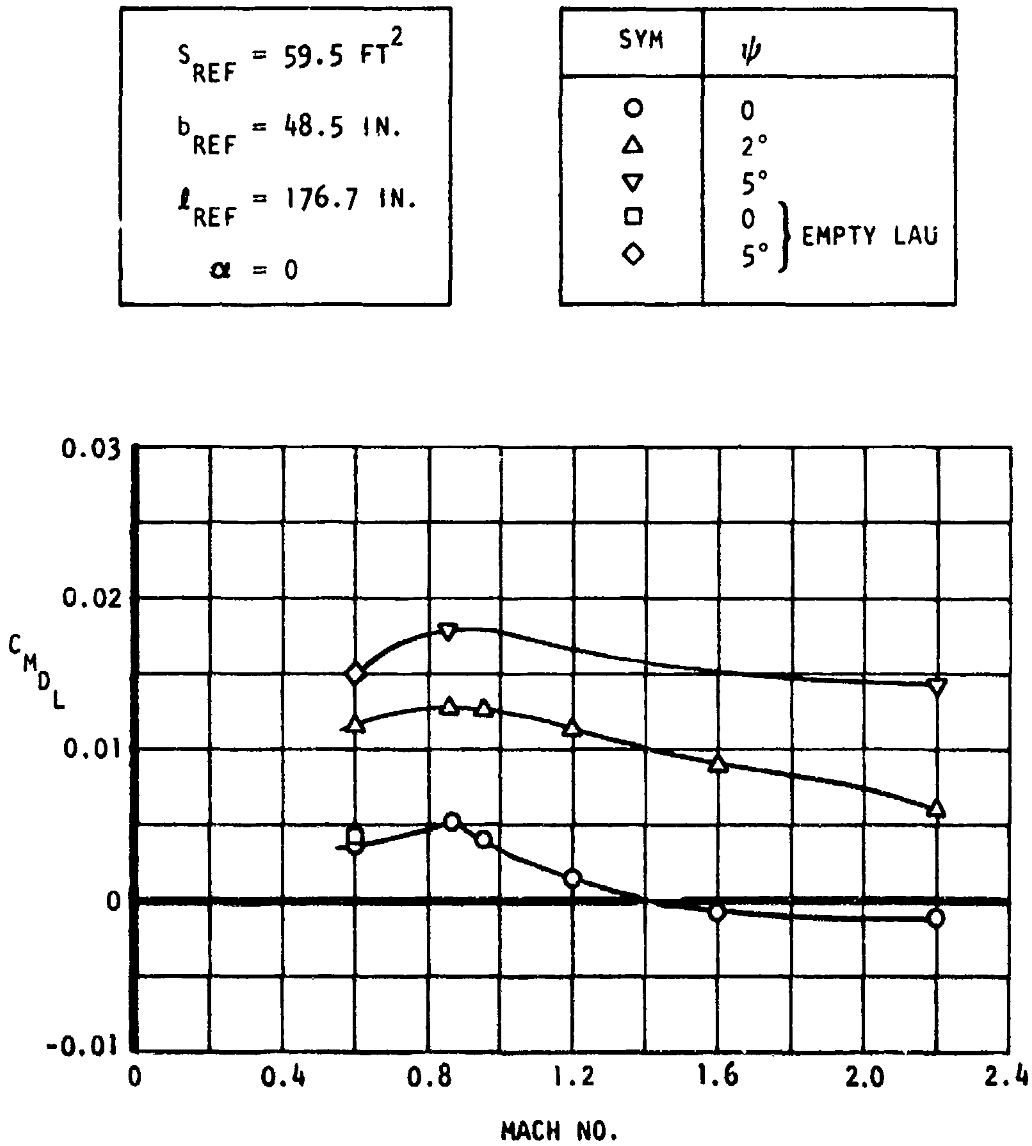


Figure 18. Forward Weapon Bay Door Loads, Hinge Moment, Left Door Half Open

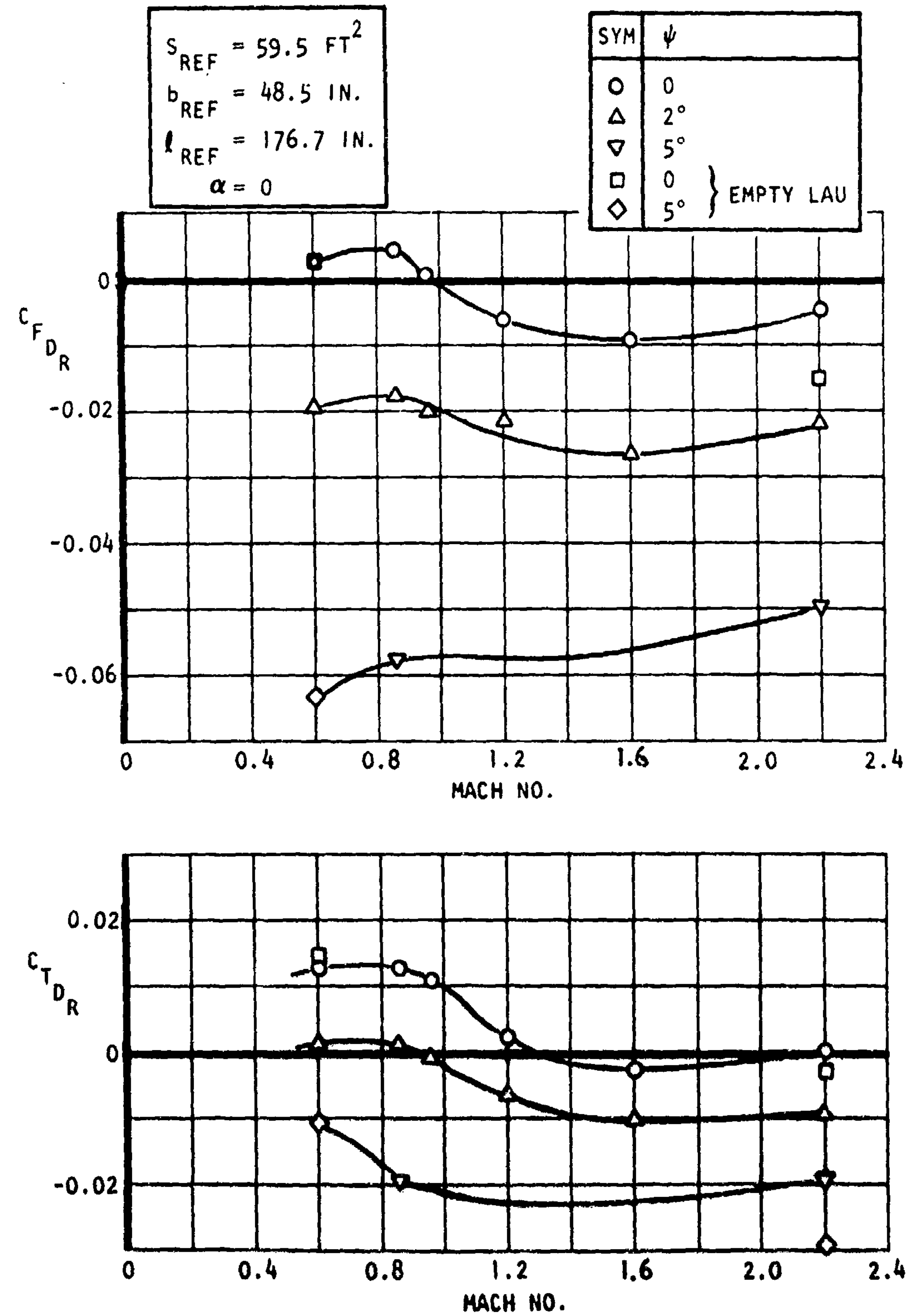


Figure 19. Forward Weapon Bay Door Loads, Force and Torsion, Right Door Half Open

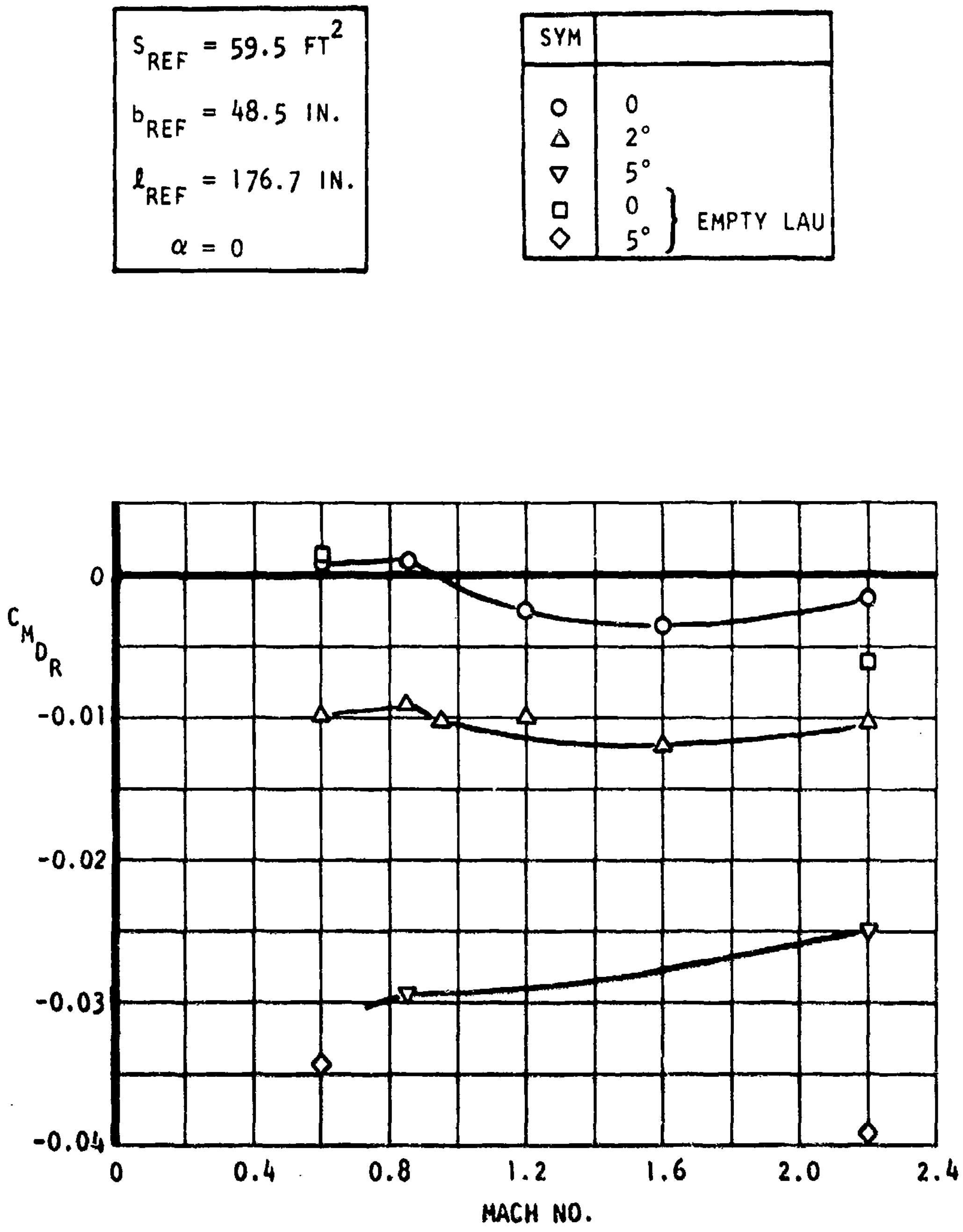


Figure 20. Forward Weapon Bay Door Loads, Hinge Moment, Right Door Half Open

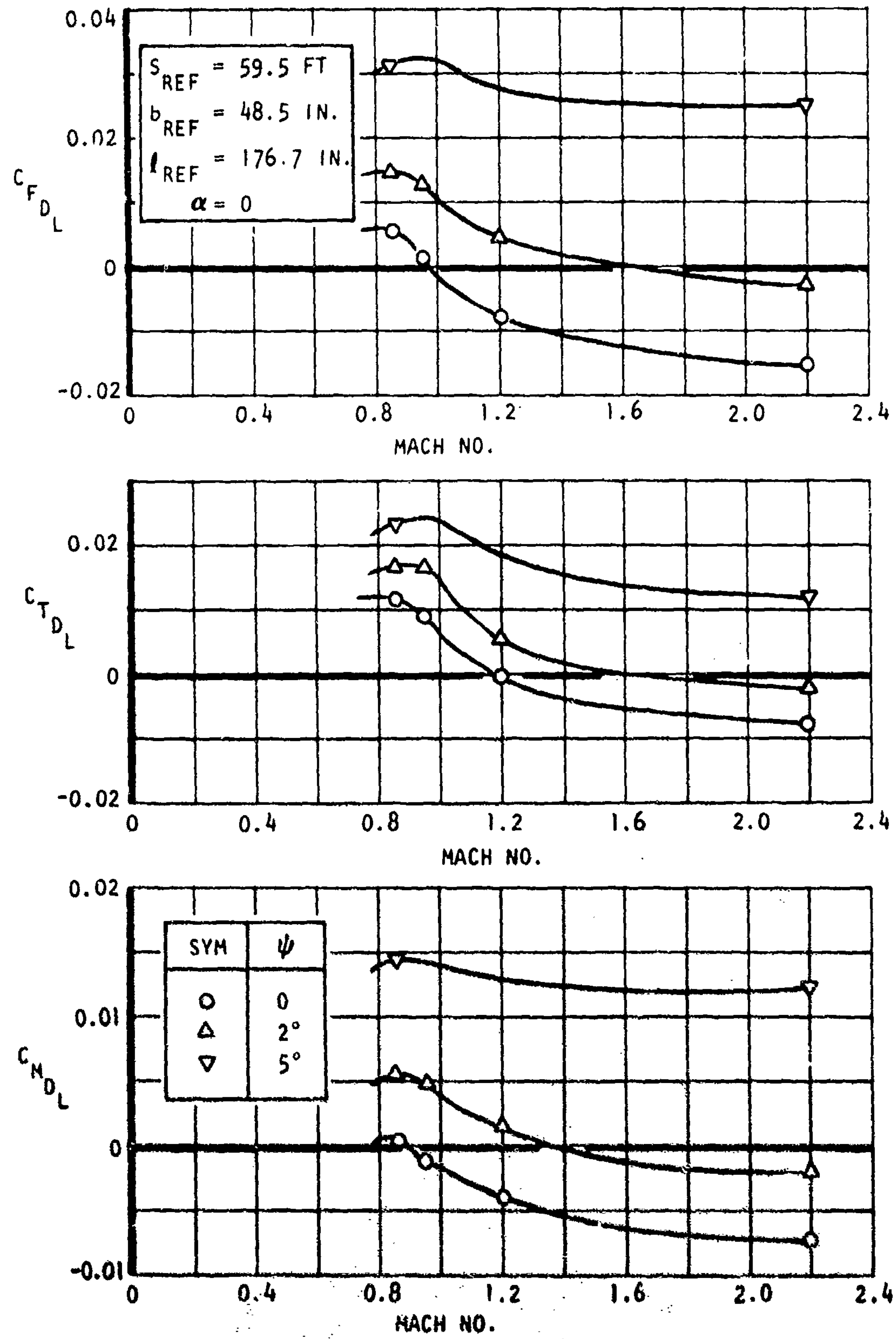


Figure 21. Mid Weapon Bay Door Loads, Left Door Half Open

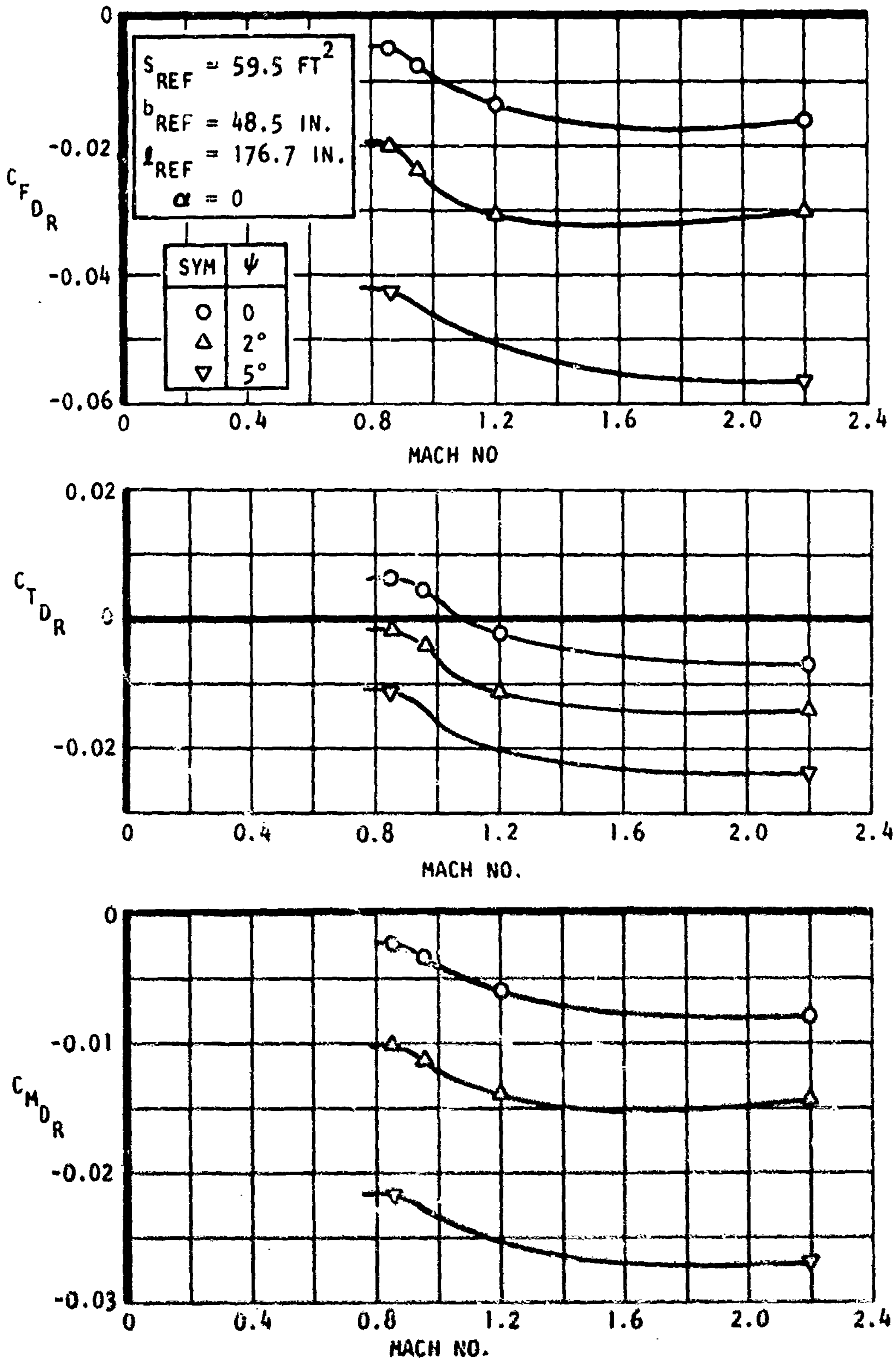


Figure 22. Mid Weapon Bay Door Loads, Right Door Half Open

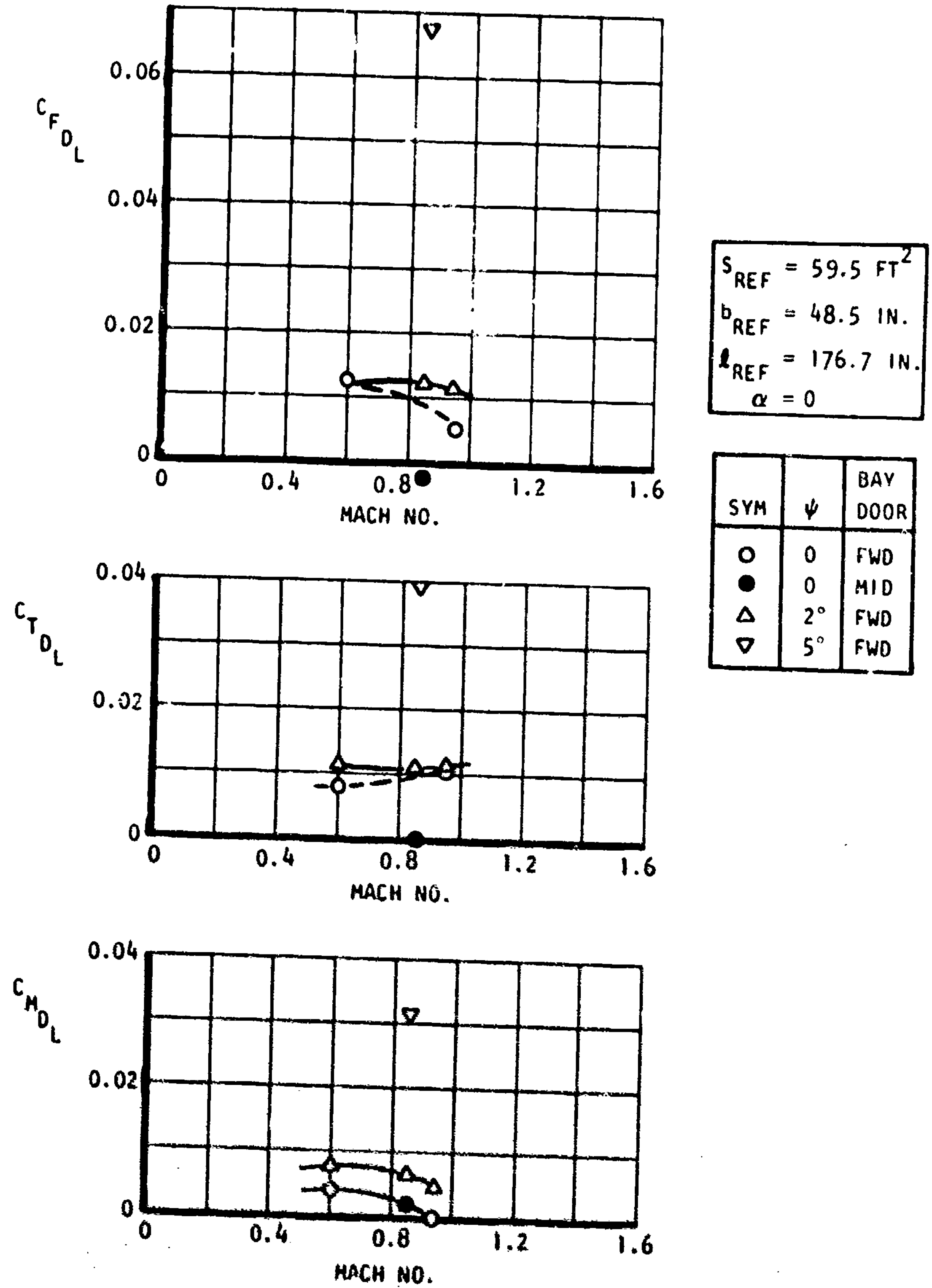


Figure 23. Forward and Mid Weapon Bay Door Loads, Left Door Full Open

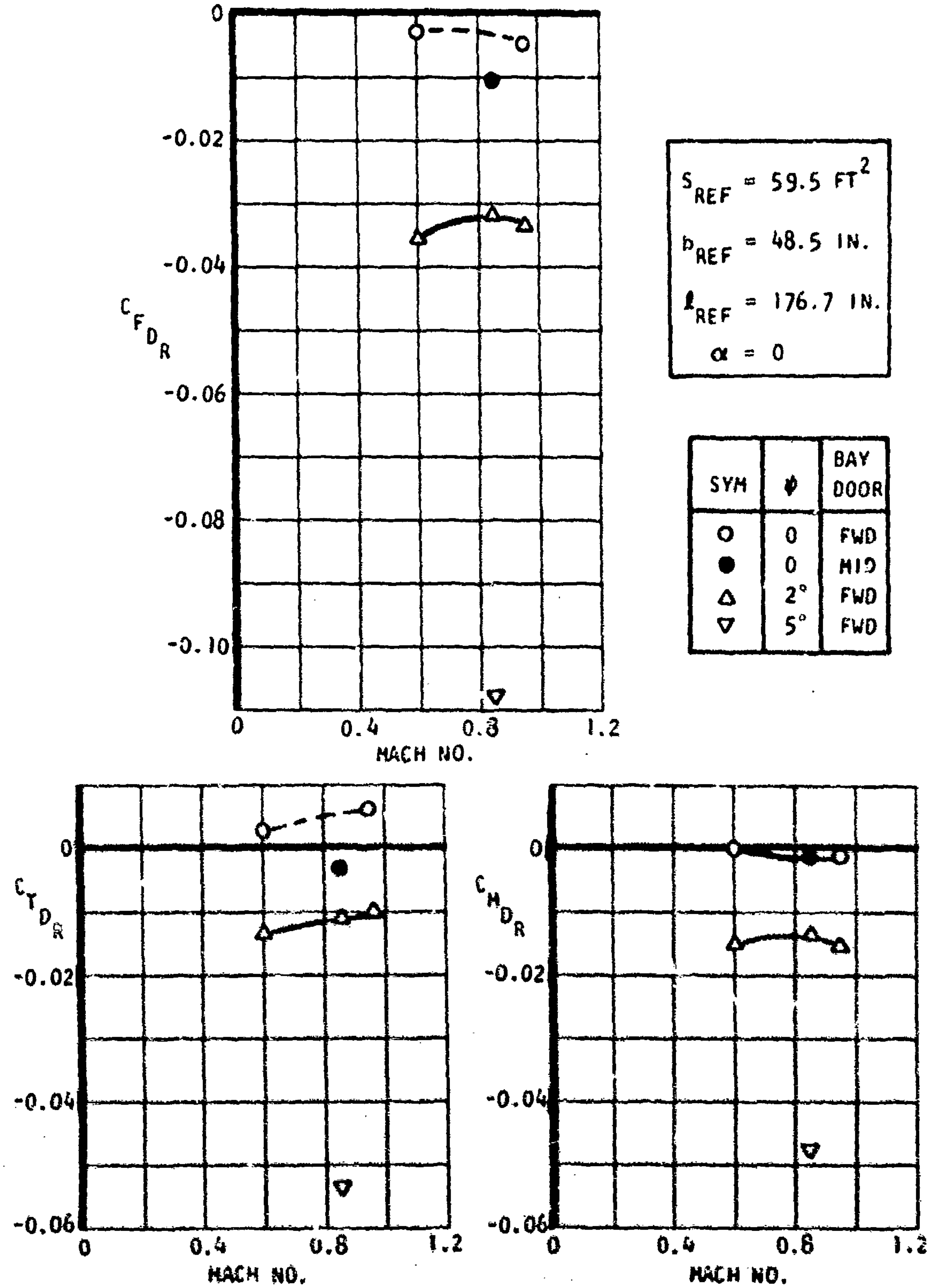


Figure 24. Forward and Mid Weapon Bay Door Loads, Right Door Full Open

S_{REF} = 59.5 FT^2
b_{REF} = 48.5 IN.
ℓ_{REF} = 176.7 IN.

SYM	α	ψ	
○	0	2°	
△	4°	2°	
□	0	5°	
◇	4°	5°	
▽	0	5°	EMPTY LAUNCHER
0	4°	5°	EMPTY LAUNCHER

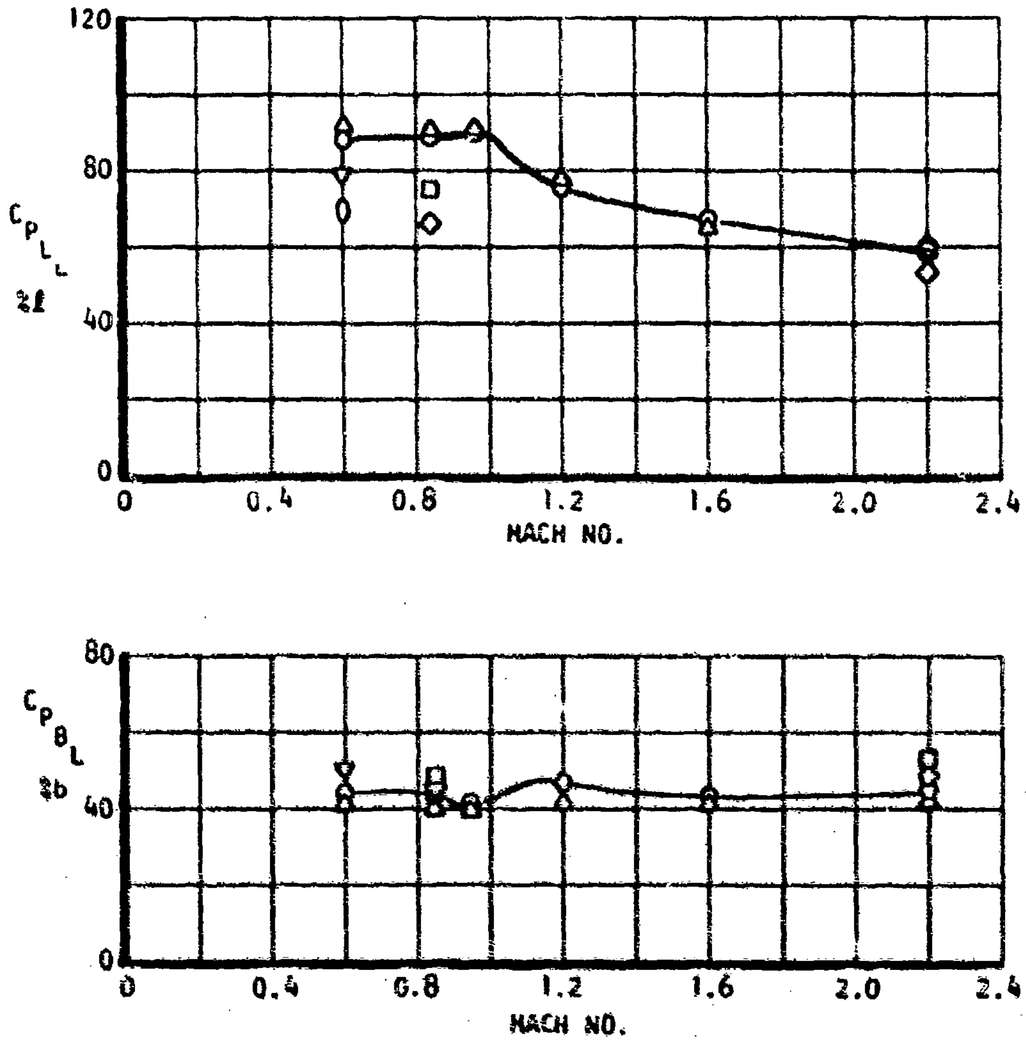
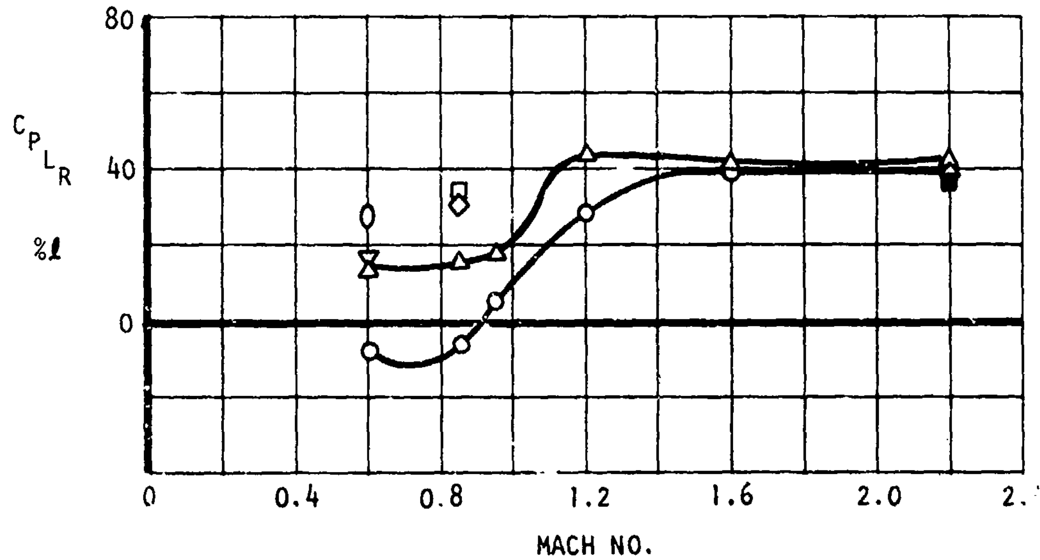


Figure 25. Forward Weapon Bay Door Center of Pressure, Left Door Half Open

$S_{REF} = 59.5\ FT^2$
$b_{REF} = 48.5\ IN.$
$\ell_{REF} = 176.7\ IN.$

SYM	α	ψ	
○	0	2°	
△	4°	2°	
□	0	5°	
◇	4°	5°	
▽	0	5°	EMPTY LAUNCHER
0	4°	5°	EMPTY LAUNCHER



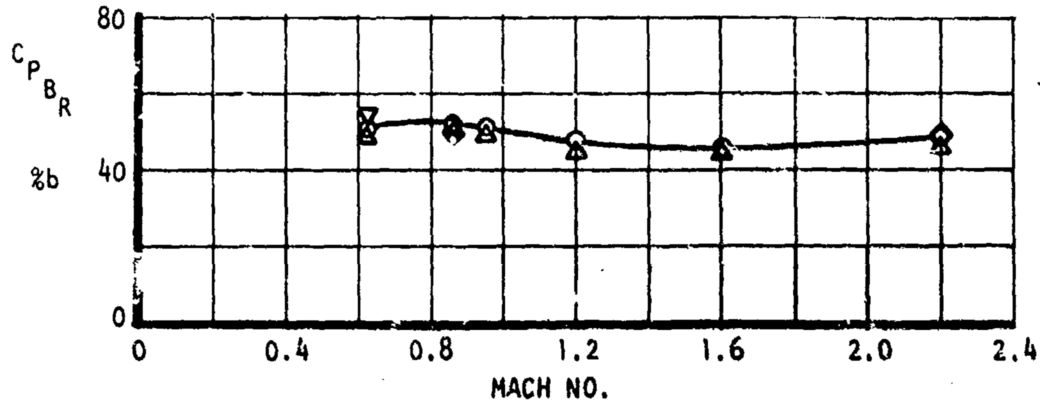


Figure 26. Forward Weapon Bay Door Center of Pressure, Right Door Half Open

S_{REF}	= 59.5 FT^2
b_{REF}	= 48.5 IN.
ℓ_{REF}	= 176.7 IN.

SYM	α	ψ
NG	0°	2°
△	4°	2°
□	0	5°
◇	4°	5°

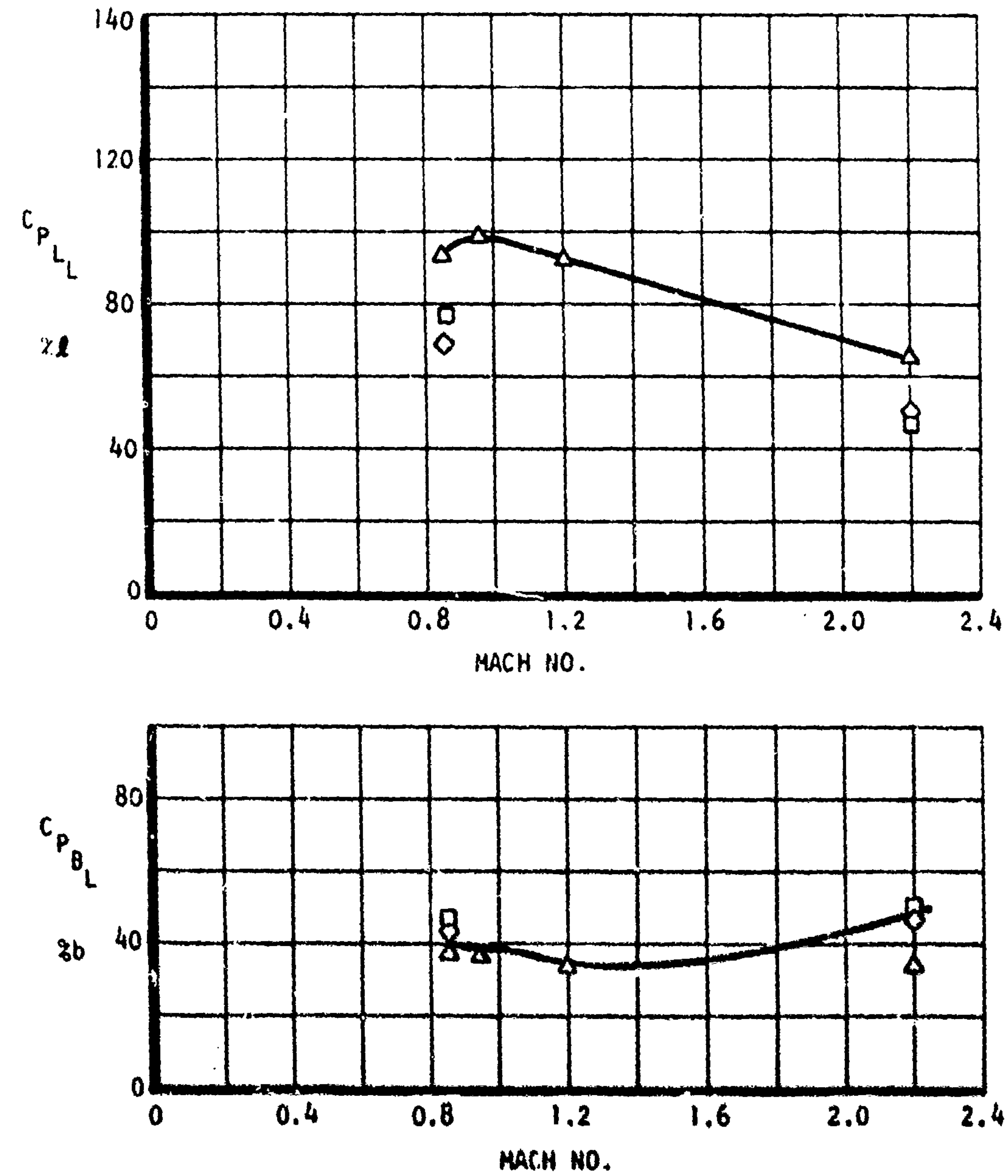


Figure 27. Mid Weapon Bay Door Center of Pressure, Left Door Half Open

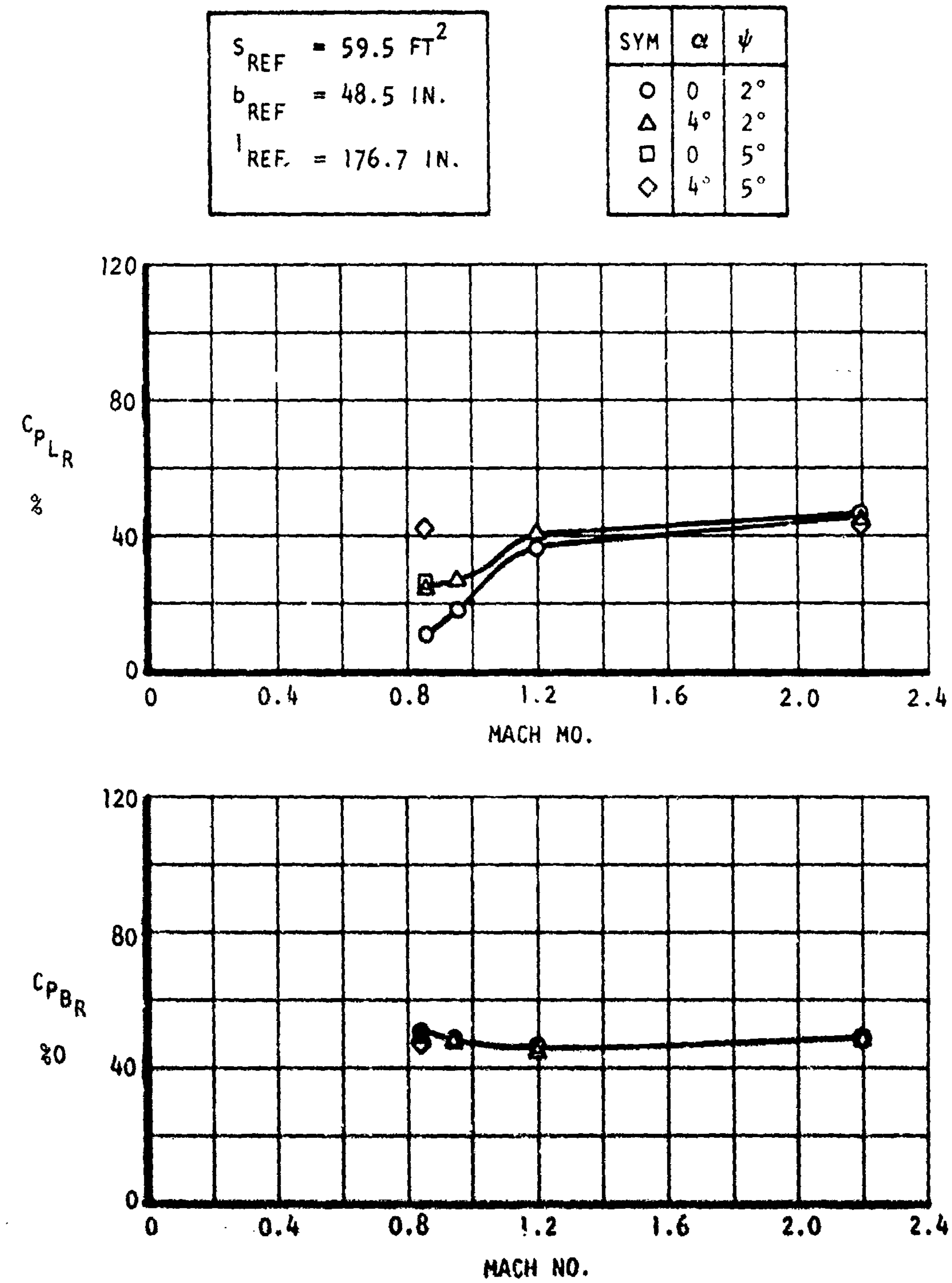


Figure 28. Mid Weapon Bay Door Center of Pressure, Right Door Half Open

$S_{REF} = 59.5\ FT^2$
$b_{REF} = 48.5$ IN.
$\ell_{REF} = 176.7$ IN.

SYN	α	ψ
○	0	2°
△	4°	2°
□	0	5°
◇	4°	5°

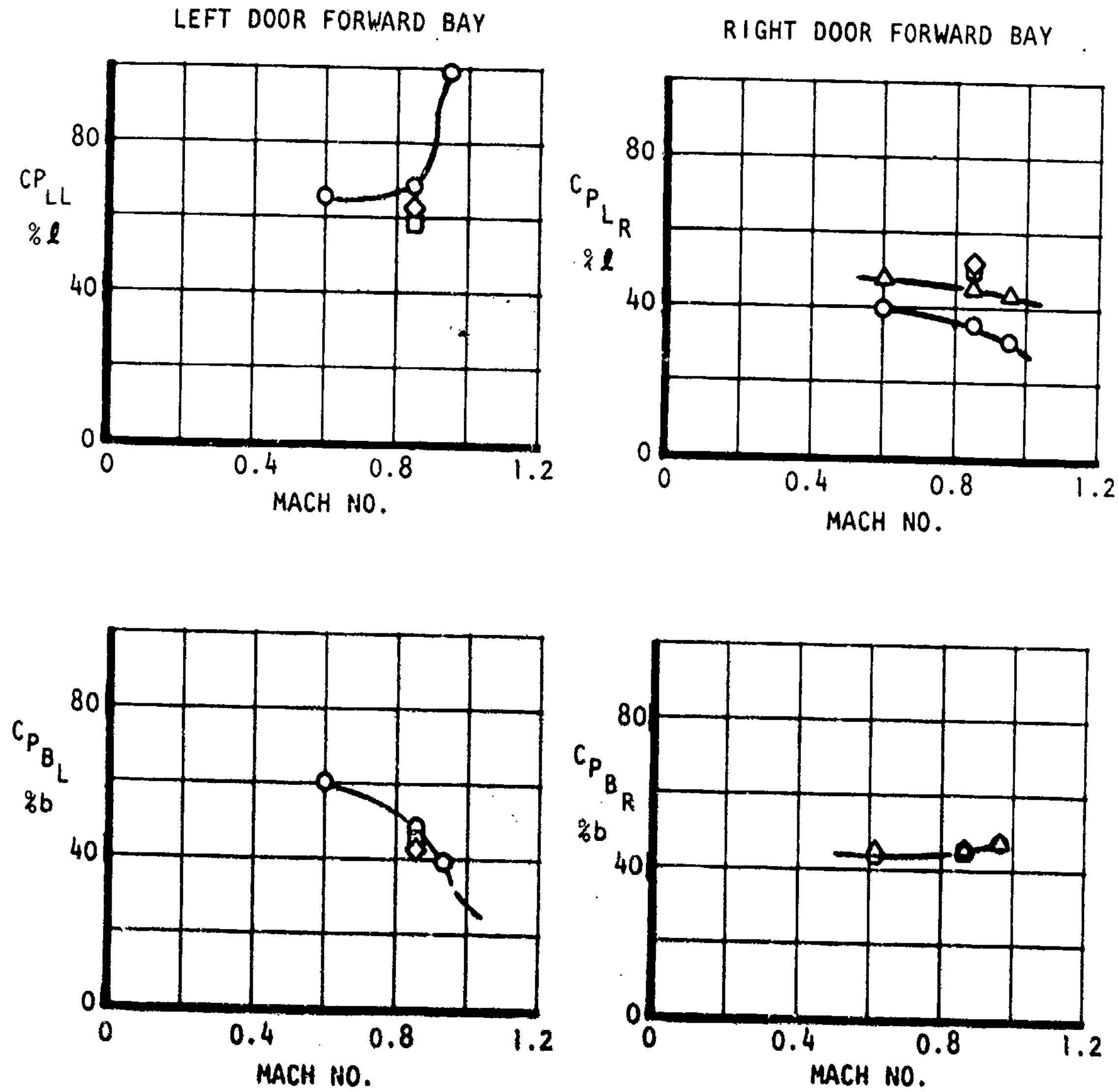


Figure 29. Forward Weapon Bay Door Center of Pressure, Forward and Mid Bay Full Open

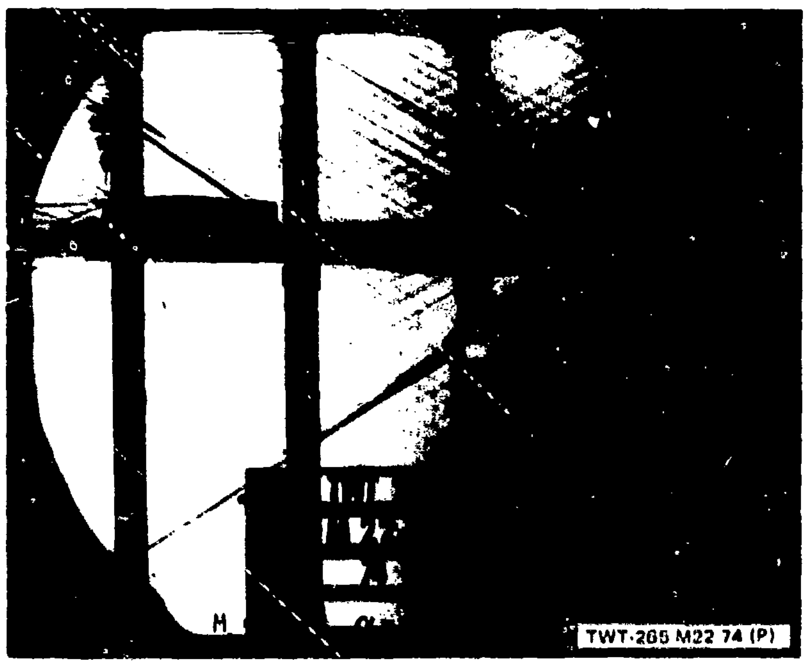


Figure 30. Schlieren Photographs: Clean Configuration

BAY OPEN, LAUNCHER FULL

BAY CLOSED, STUB DOORS

Figure 31. Schlieren Photographs: Forward Doors Half Open, Bay Open and Closed M = 1.6

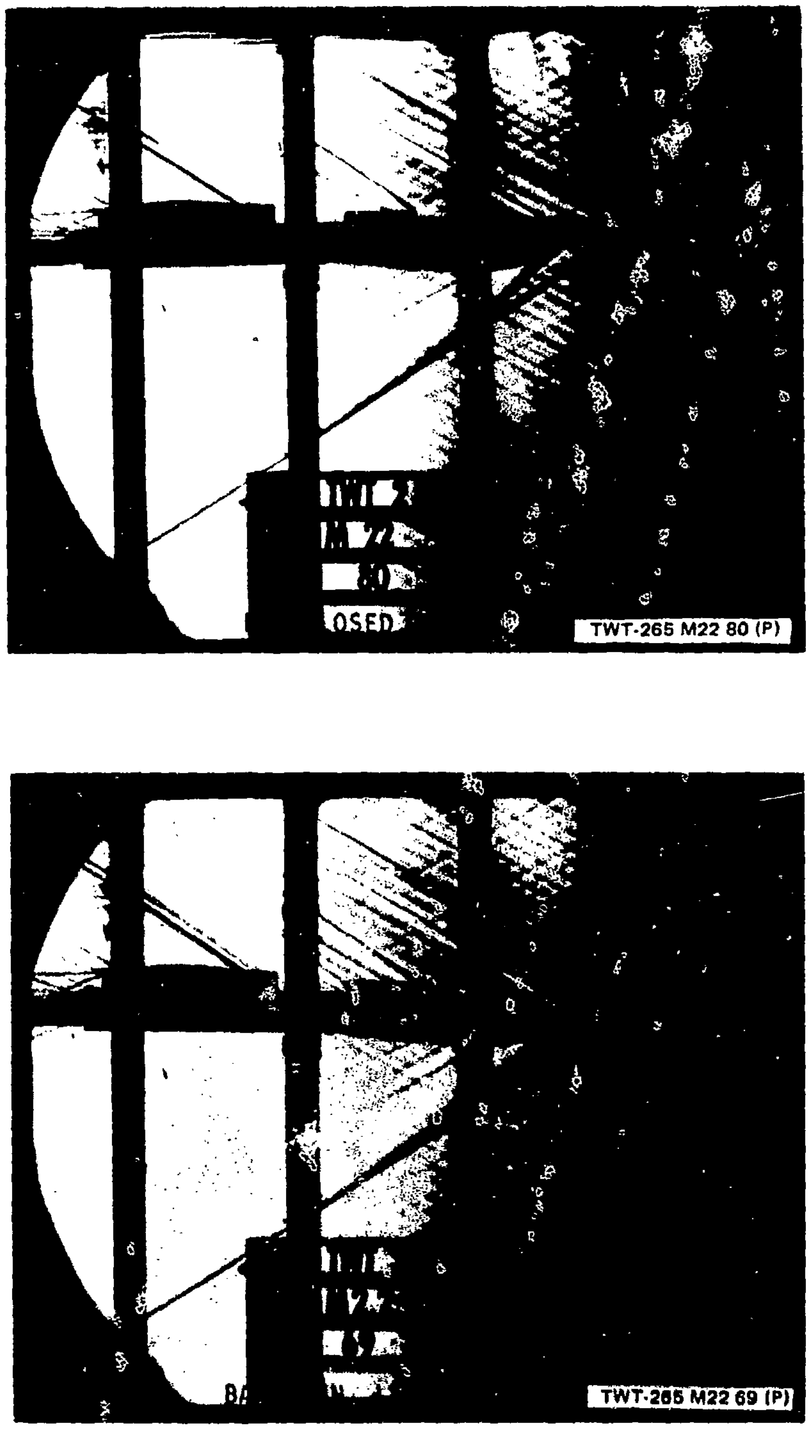


Figure 32. Schlieren Photographs: Forward Doors Half Open, Bay Open and Closed M = 2.2

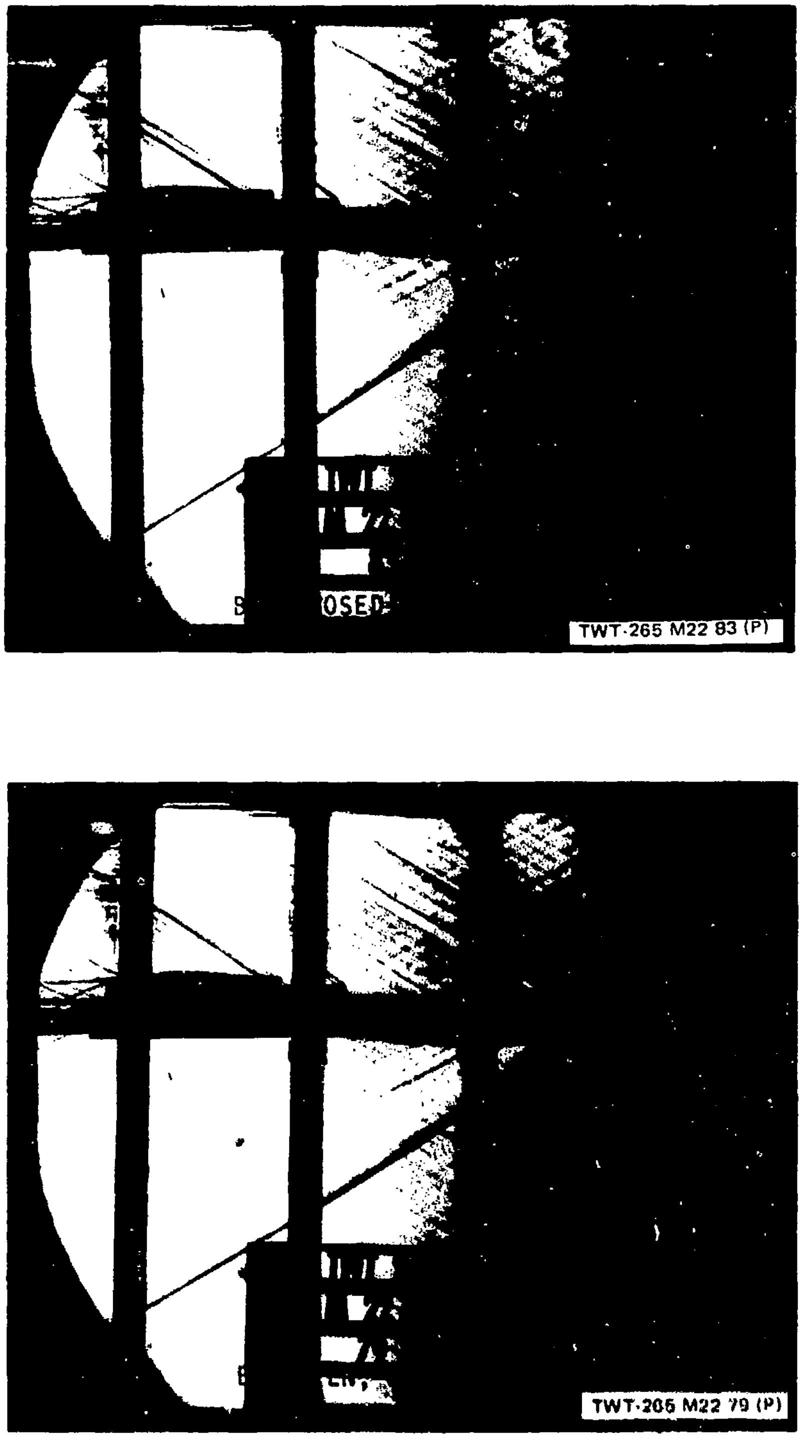


Figure 33. Schlieren Photographs: Mid Door Half Open, Bay Open and Closed (M = 2.2)

CONCLUSIONS

1. The general conclusion from this test is that the model and methods employed are a satisfactory means of defining the incremental effects on air vehicle aerodynamic characteristics of open weapon bays and weapon bay doors.

2. The basic aerodynamic incremental data follow expected trends, with the exception of the incremental rolling moment. Increasing yaw angle produces positively increasing rolling moment. This trend is consistent at all mach numbers, and is consistent for either or both bays and for bays open or bays closed. This trend suggests that the increment in side force acting on the doors is less effective in roll than the interference load on the lower surface of the body and wing glove.

3. The door loads data show logical variations with mach number and yaw angle.

4. The longitudinal stability changes due to all open bay and door configurations are negligible.

5. The lateral directional stability changes due to all open bay and door configurations are either small or negligible. Forward bay doors show an incremental directional stability loss, while the mid doors produce a negligible effect.

REFERENCES

1. "Aerodynamic Characteristics of Open Weapon Bays on the B-1 Weapon Separation Model TWT-265," NA-72-1002, Rockwell International, B-1 Division, December 1972.

2. "Pretest Information for the B-1 Store Separation Model II Force Test in the Trisonic Wind Tunnel (Test 3)," NA-70-550-2, revised July 1972, Rockwell International, B-1 Division, September 1970.

AUTOBIOGRAPHY

R. E. Little, Member of Technical Staff, Aerodynamics Group, Rockwell International/Aerospace Group. For the past 3 years, Mr. Little has been engaged in the definition of the B-1/weapon separation characteristics as they relate to aerodynamics. This activity included subsonic and supersonic wind tunnel testing at AEDC and Rockwell wind tunnels. He was also responsible for the application of these results in analytical studies defining B-1 weapon separation envelopes.

Additional activity in the weapon separation field include definition of the upcoming flight test program including data analysis of weapon drops, as well as B-1 aerodynamic performance requirements for flight test.

Mr. Little has been connected with the Aerodynamics Group at the Los Angeles facility for 29 years.

RESULTS OF EXPERIMENTAL AND THEORETICAL INVESTIGATIONS INTO THE MECHANISM OF MUTUAL RETARDER WAKE INTERFERENCE BETWEEN PAIRS OF RETARDED 1000LB BOMBS

(UNCLASSIFIED)

by

KEITH G. SMITH

Hunting Engineering Limited, Ampthill, England.

ABSTRACT. Results of experimental and theoretical investigations into the mechanism of mutual retarder wake interference between pairs of retarded 1000lb bombs have been presented. Experimental data was obtained from releases of pairs of bombs from a Buccaneer Aircraft and from wind tunnel tests conducted on a tandem pair of $^1/_9$th scale model bombs. A mathematical model has been developed and its validity established using the wind tunnel data to simulate flight trial releases. Subsequently the model has been used to study the mutual interference problem.

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LIST OF FIGURES

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INTRODUCTION

During 1965 a contract was placed on Hunting Engineering Limited to assess the collision risk between retarded stores as it was thought that store/store collisions could present a safety risk to the delivering aircraft. To study the problem a computer simulation model was developed capable of coping with the large number of parameters involved in the assessment of collision/interference probability.

Results of initial studies using the simulation model did not produce the degree of correlation with the trials results that was expected. Reasons for the rather poor correlation were attributed to

(i) Lack of knowledge of the phenomena of retarder wake effects and its association with release disturbance effects

(ii) Unknown accuracy of weapon system timing.

In 1971 Hunting Engineering Limited were tasked with identifying the above problem areas by initiating trials and theoretical studies necessary to provide data allowing the mechanism of store to store interference to be defined. With the data available it was anticipated that an accurate simulation model would be developed for use in studying the interference problem on current "in service" U.K. aircraft.

This paper concentrates on the area of retarder wake interference effects and the association with release disturbance.

RETARDER SHIELDING TRIALS

At the start of the study the only trials data available was that for "stick" releases of the retarded 1000lb bomb from the Vulcan and Canberra aircraft. These data were of a very limited nature and consisted of only high speed cine records. Flight trials were therefore initiated using all the necessary range equipment to provide data required.

To study the more fundamental nature of the interference problem a series of wind tunnel trials using a tandem pair of stores was initiated. It was anticipated that the results of wind tunnel trials would be used in mathematical modelling studies simulating the flight trial releases.

FLIGHT TRIALS

The Buccaneer Aircraft was selected as the trials aircraft because of its availability, the relatively close spacing of stores carried in the bomb bay and its well known performance capabilities. Store releases were planned to be made from all four bomb bay positions, two pairs being released per sortie. However, due to the mod. state of the aircraft, it was only possible to carry two stores per sortie. The carriage positions in the bomb bay and the release order (nominal) are illustrated in figure 1.

Using kinetheodolite results obtained from previously conducted clearance trials, the effects of release disturbance on the movement of the stores in both the vertical and lateral planes was derived. This data, together with nominal aircraft weapon system timing data, was used in the simple simulation model to predict probabilities of store to store collision for a release speed of 450kns E.A.S. as a function of stick interval and release positions, see table I.

TABLE I PROBABILITY OF STORE-STORE COLLISION (RELEASE SPEED 450KNS E.A.S.)

RELEASE POSITIONS	STICK INTERVAL (s)		
	0.06	0.15	0.25
5 - 6	94%	47%	5%
7 - 8	92%	44%	5%

Based on the predicted probabilities presented in table I a stick interval of 0.150s was selected for initial trial releases from stations 5 and 6.

Prior to the commencement of the trials, discussions were held with the range authorities to establish range instrumentation requirements and stress the importance of obtaining the required data.

Initial trials were conducted with a stick interval of 0.150s (nominal) and in the first five trials severe interference between stores was observed. On examination of the data the actual stick interval was found to be 0.144s. In further trials it was decided to increase the stick interval to a nominal 0.180s. To achieve this interval without modifications to the aircraft electrical system it was necessary for the releases to be made from bomb bay stations 5 and 8 (i.e. from "in line" stations). Results obtained from these releases indicated with the nominal 0.180s interval little or no interference

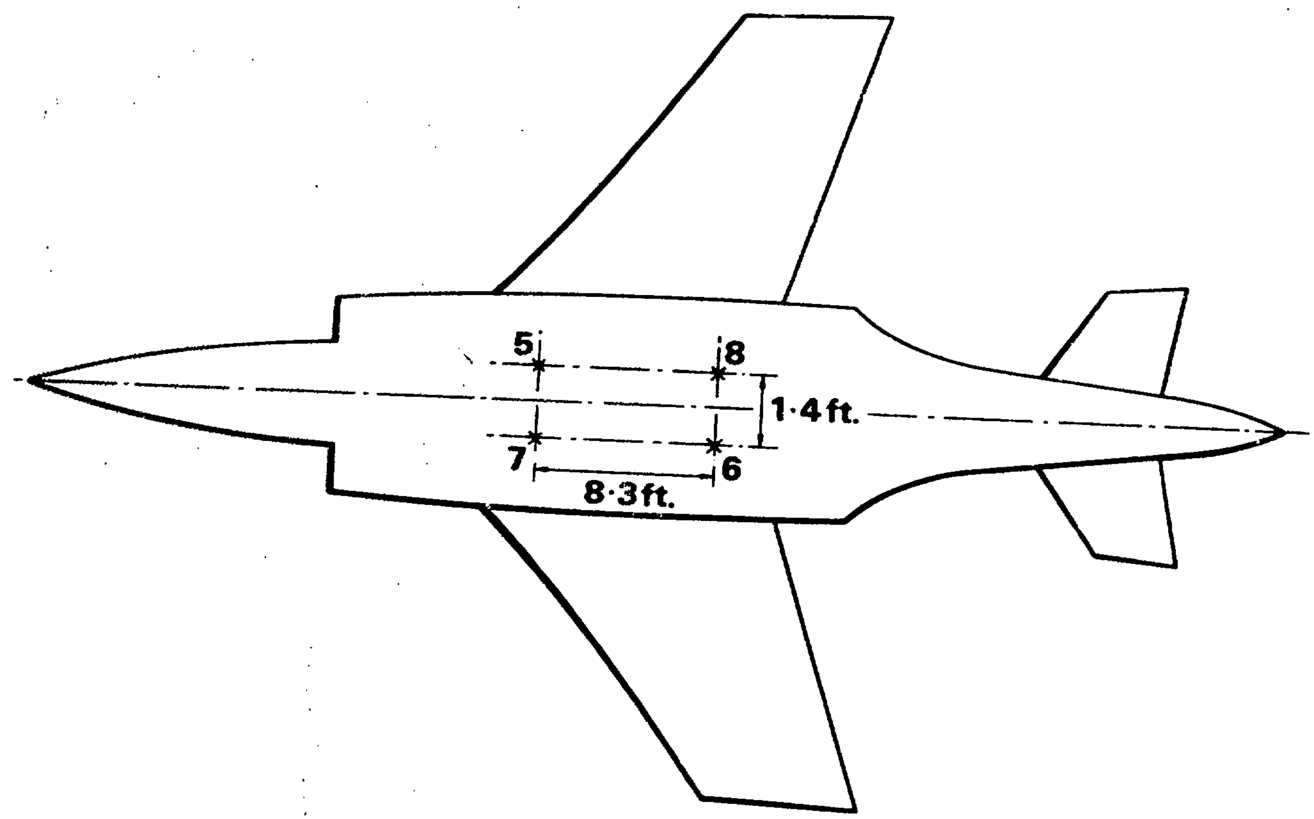


Fig.1 Plan View of Buccaneer Aircraft Illustrating Bomb Bay Carriage Positions

between stores. Further examination of the data confirmed the actual interval to be 0.176s.

To investigate the effect of the nominal 0.180s interval for releases from stations 5 and 6 it was necessary to modify the aircraft electrical system. The results obtained for this release order confirmed the results previously obtained for releases from stations 5 and 8, i.e. insignificant interference. Finally, for completeness, releases from "in line" stations 5 and 8 were made with a nominal stick interval of 0.150s and serious interference effects were observed.

The flight trial results indicated the interference effects between the stores to be very sensitive to stick interval i.e. severe interference at 0.144s, little interference at 0.176s. It was therefore not possible to deduce data from these trials to help the development of a realistic mathematical simulation model.

In an attempt to obtain reasonable amounts of "capture" (interference) between pairs of stores a further six trials were conducted with nominal stick intervals of 0.160s and 0.170s. For these trials actual stick intervals, based on the earlier trials evidence, of 0.154s and 0.166s were expected. However, actual intervals measured in the trials were 0.010s less than those expected.

WIND TUNNEL TRIALS

These trials were initiated to obtain a more fundamental understanding of the interference effects between retarded 1000lb stores. The trials were programmed for the 9ft x 8ft transonic wind tunnel of the Aircraft Research Association at Bedford.

To obtain the interference effects in the wind tunnel it was proposed to use a fixed model bomb and another, forward bomb supported on a mechanism to vary lateral displacement. The forward bomb could be mounted at different axial stations so that the effect of separation might be measured on the rear bomb in terms of drag loss, normal force and pitching moment. An independent variation of incidence of the rear bomb was designed into the support system so that rear bomb stability as a function of its proximity to the wake could be investigated.

A number of difficulties were envisaged at the outset, the most important being how closely the stores should be modelled with regard to the fabric parts of the retarder; whether loads could be measured sufficiently accurately on the rear bomb immersed or partly immersed in the wake of the front bomb; and whether it would be possible to support the front bomb by a simple tow wire to allow easy adjustment of the separation between them. If relatively accurate retarder parts were considered necessary, there were doubts about the life of the necessarily small scale components.

The rear bomb had to be carried on a balance capable of measuring unusually high drag in relation to pitching moment and lift, and supported on a system capable of relatively large incidence and vertical traverses. The arrangement in the tunnel allowed two rotations about different points approximately 40" apart, thus vertical movement of up to 20" and angles of up to 20° were possible in reasonable combinations.

The initial, development, tests were conducted using a rear bomb in isolation. Following minor changes, the program of trials was completed without serious difficulty.

Model Details

The models of the retarded 1000lb bomb were made with the retarder canopy extended, and with the arms able to swing radially, between 30° and 70°, restrained by strops as in the full size retarder. Although basically similar, the front model had arrangements for support via a ½" dia. rod entering the nose, while the rear bomb was carried on a balance from behind.

The bomb central tube on which the fins are carried and from which the arms supporting the retarder canopy pivot, was too small to allow a balance to be contained within, so this part was extended rearwards and increased in diameter to fit the taper joint of an existing 1" diameter balance.

The representation of the canopy was based on the full scale configuration, and was accurate regarding the number of ribbons, porosity, shape and rigging lines, and was constructed from ¼" wide ribbons (representing 2" full size ribbons) but no serious attempt was made to simulate the gore stiffness. The scale using this material should thus be ⅛ full size.

Confidence in the model canopy, which was designed and manufactured by Irvin GB Ltd was demonstrated in a preliminary test made with the rear bomb in isolation. The prototype parachute canopy and its attachments to the arm were found generally satisfactory and few modifications were required, also the tests showed that the life to be expected was at least 1½ hours, outside the wake. During the main test program, the rear model canopy repeatedly suffered minor damage, the forward canopy was changed twice but remained undamaged.

The front bomb - rear bomb separation was limited to 87" because of the incidence and height mechanism which had to be attached to a joint on the standard complete model cart. The support for the front bomb was a swept-forward strut carried on a removeable perforated floor ahead of the model cart, allowing all model rigging to be done outside the tunnel. Axial separation distances of about 4 body lengths (4ℓ) to 10ℓ were required, indicating a scale of approximately $^1/_{10}$th would be necessary. However, it was required to match estimated drag to the

performance of an existing balance, and to use as large a model as possible to allow detailed bomb components to be manufactured more easily. Thus a compromise scale of $^1/_9$th was chosen allowing separation distances of up to 9ℓ and permitting the use of $\frac{1}{4}$" ribbons to be representative of 2" full size ribbons. The assembled rear bomb is shown in figure 2.

When at maximum separation (9ℓ and 8.4ℓ) the front bomb was supported on a solid rod, (see figure 3) but the fatigue of this became unacceptable when the rod exceeded about 3 bomb lengths, due to the model responding to the rough flow in the wake. For the 7ℓ separation ratio tests, therefore, a 2000lb multistranded steel wire was used but this broke after about 10 minutes at a Mach number of 0.8, fortunately only destroying the front bomb, (the drag of which does not exceed 200lb.). Next a nylon braided line of 900lb. capability was used, but again the first bomb was lost after $\frac{3}{4}$ hour, the failures occurring at the ferrule within the model nose, apparently by fatigue in the wire and from the generation of heat in the nylon from flexing. Although the bomb was highly stable about the nose tow point, clearly towing from further ahead would be necessary to avoid further failure and all subsequent tests were made using a tube (with inserted high tensile wire as a safety device in case of tube failure) suspended on the joint at the strut to restrict the bending moment developed at that point. Varying tube lengths positioned the front bomb at separation ratios of 6, 5 and 4 body lengths and no further trouble was experienced in the tunnel tests.

Test Program

The range of height of the rear bomb above the front was varied from 0 to 2 body lengths (20") the incidence limits were $\pm 15^\circ$ and separation ratios between 9 and 4 body lengths and of course an infinity case i.e. the rear bomb in isolation. Results of 5 components from the balance were obtained on the rear bomb, axial force, normal force, pitching moment, side force and yawing moment, the lateral components being recorded as a check on the symmetry of the bomb and showed to be a useful indication of parachute damage. The tests were made at Mach numbers of 0.6, 0.7 and 0.8.

The aerodynamic characteristics, axial force, normal force and pitching moment were also obtained for the isolated bomb so that interference effects acting on the rear bomb, when within the diffused wake of the forward bomb, could be isolated. All aerodynamic forces and moments were non-dimensionalised using the bomb body cross sectional area and its diameter, the moment reference position being 47.5% of body length.

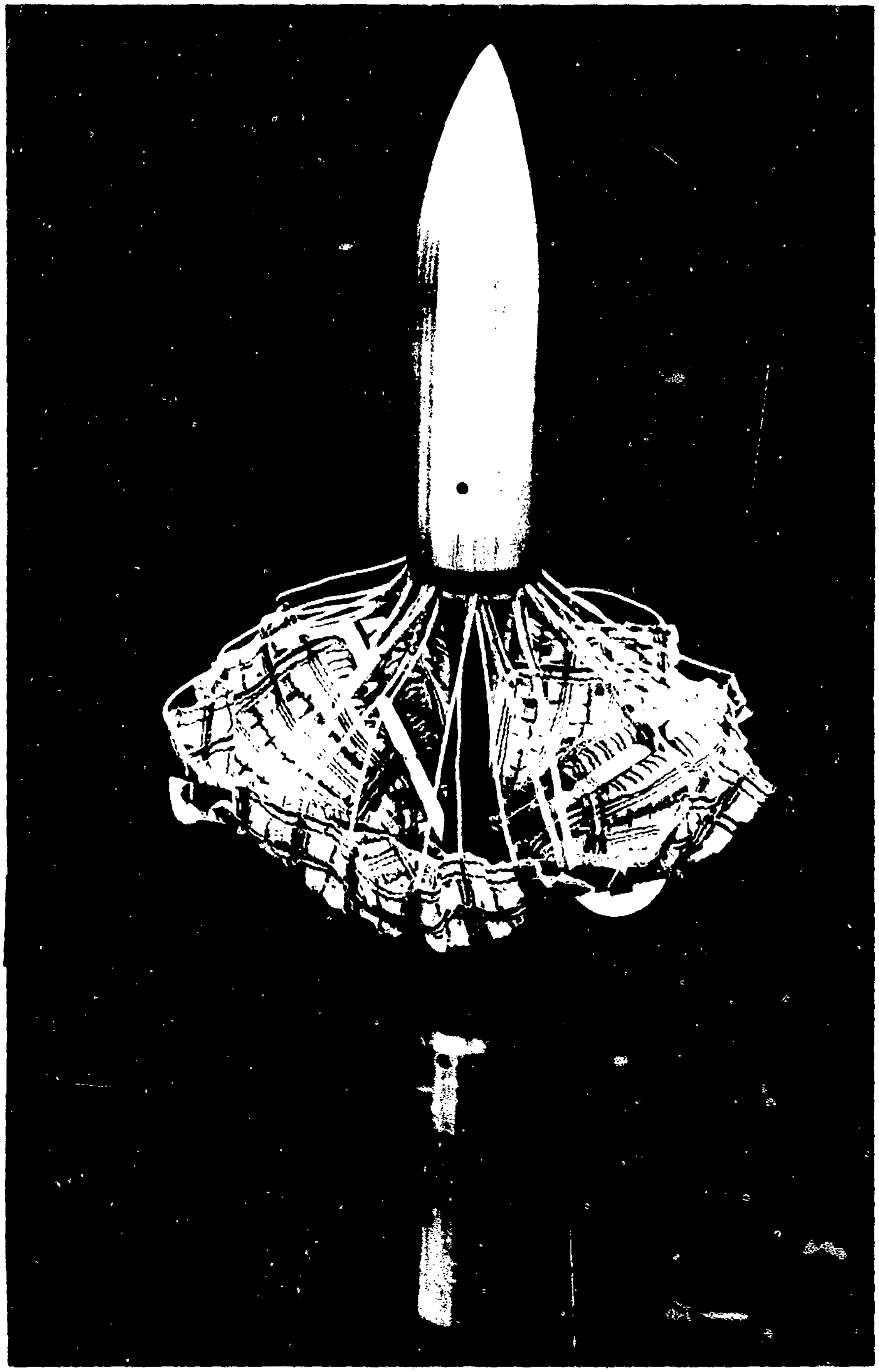


Fig.2 The Assembled Rear Bomb

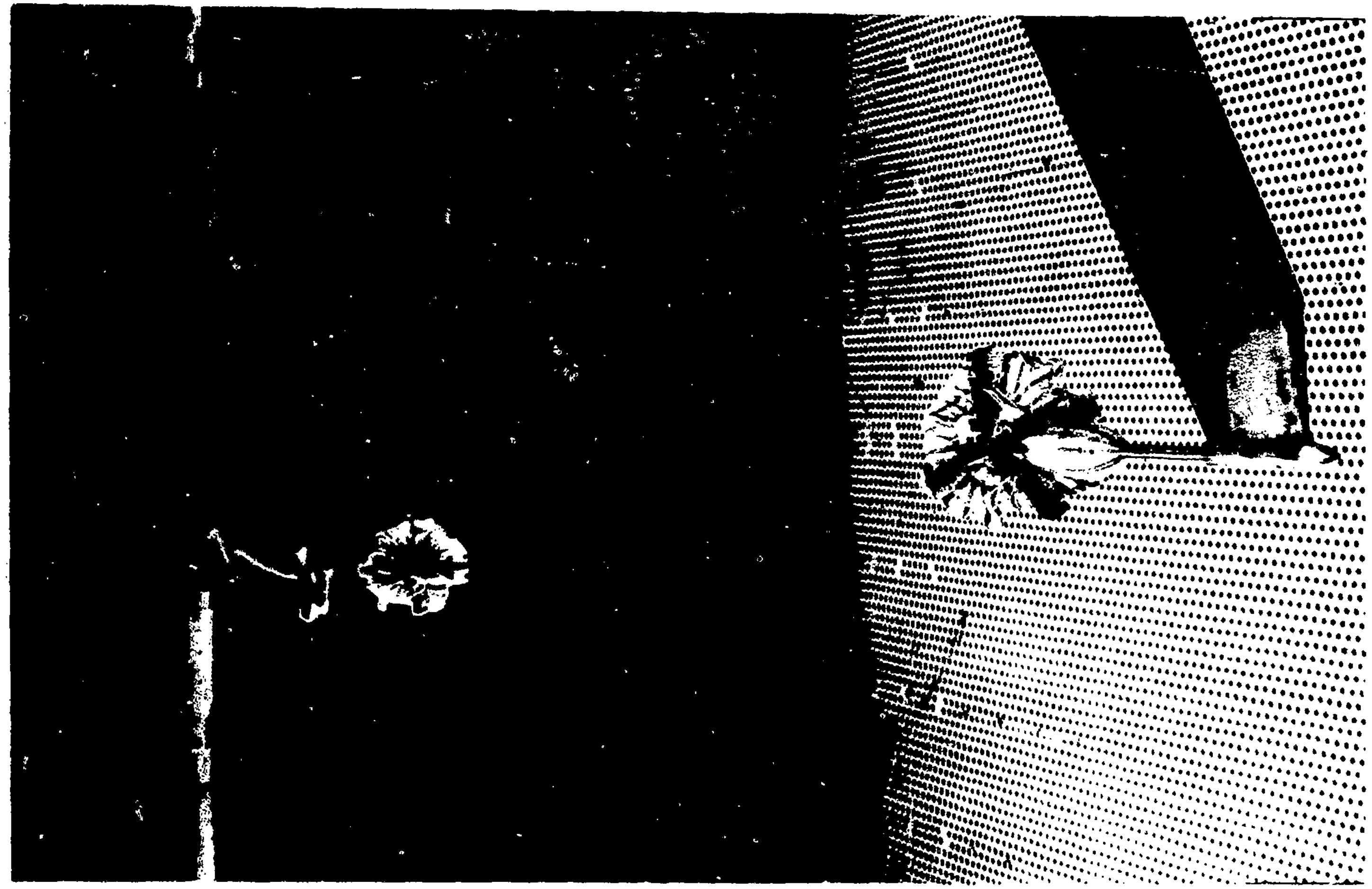


Fig.3 The Tandem Bombs Mounted in the Transonic Wind Tunnel

Wind Tunnel Tests

The tests were conducted in the Aircraft Research Association 9ft x 8ft transonic wind tunnel which has a 20% (approximately) open area perforated walls, the rear model being carried on a complete model cart, the front support strut on the perforated make-up cart.

The solid blockage of the models, separately or together, was negligible and the wake blockage was considered to be small enough to have a negligible effect on the tunnel velocity. The total drag area ($C_x S$) was approximately 0.3ft^2, or less than 0.5% of tunnel cross-sectional area. This value did not require any corrections to be applied to the reference pressures, particularly in a tunnel of this description. All tests were conducted at atmospheric stagnation pressure.

The rough flow in the wake from the front canopy created very unsteady readings on the rear bomb balance, but the tunnel instrumentation had the provision of averaging the readings over approximately a second and no other special measures were taken. Nevertheless, at separation ratios less than 6 and small lateral offsets, the rough flow was responsible for a lot of damage to the rear canopy, some of which may not have been noticed before the damage became severe. The results were therefore carefully scanned for non-zero lateral readings and other peculiarities; and suppressed if doubtful.

Data Reduction

Calculation of rear model incidence and lateral offset is made from the relationships:

$$\theta = \theta_c + \theta_s \tag{1}$$

$$h = 10 - 54{\cdot}8 \sin\theta_c + 32{\cdot}57 \sin(\theta_c + \theta_s)\cos\theta_c \tag{2}$$

The sign convention and symbols used are defined in figure 4.

Direct measurement at each test point showed the incidence to be within 0.25^0 and offset within 0.3", the repeatability was within 0.2" or 2% of body length.

The base pressure in the balence cavity under the shroud was used to correct axial force to free-stream static pressure. The pressure immediately behind the rear canopy was also measured as some doubt existed whether the bluff assembly support might affect canopy drag. Additional tests with a blockage created by a 6" diameter plate mounted on the sting (see figure 5) showed that neither the canopy pressure nor drag was affected when the plate was moved over a range of 9" to 16"

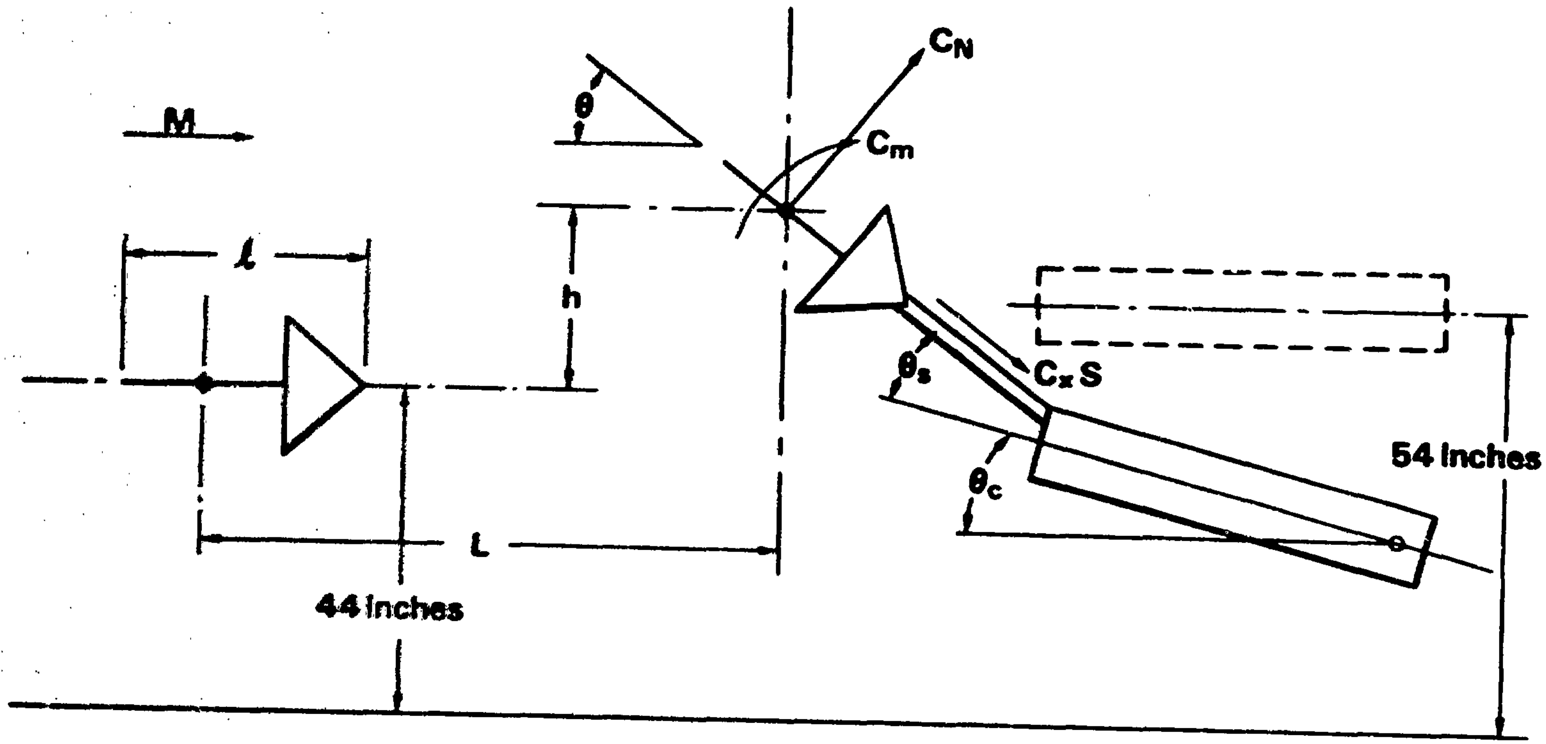


Fig.4 Wind Tunnel Sign Convention and Definition of Symbols

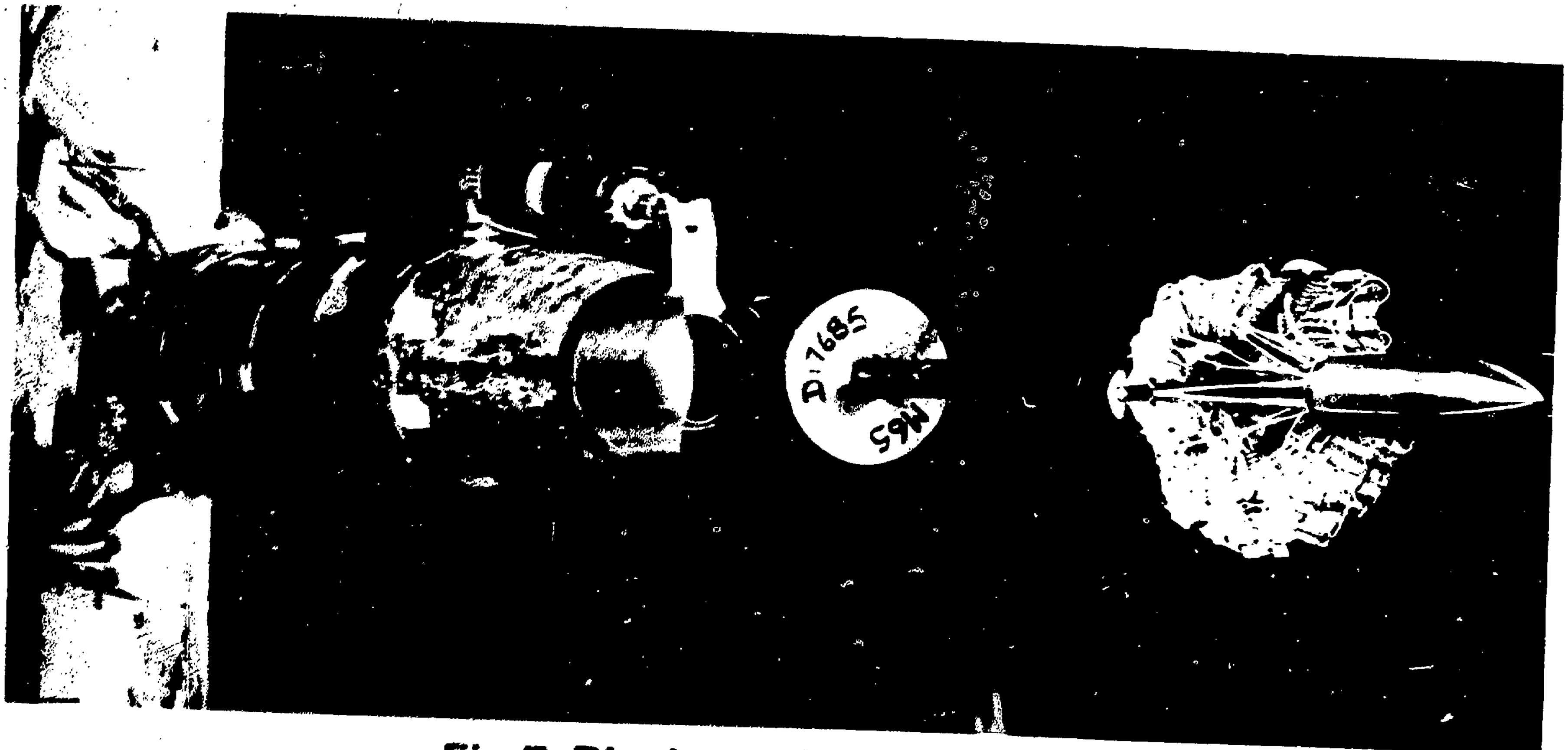


Fig.5 Blockage Plate Mounted to Determine Bouyancy Effects

behind the canopy. It was therefore concluded that the support system did not introduce spurious effects on the drag due to the buoyancy effect.

ANALYSIS OF RETARDER SHIELDING TRIALS

FLIGHT TRIALS

The data obtained from the trials generally related to situations where either severe interference or relatively little interference occurred between the stores. Analysis of the kinetheodolite and high speed cine records did not permit data relating specifically to the problem of store-store interference to be deduced. However, data was obtained which could subsequently be used in an attempt to validate the mathematical model to be developed for simulating interference effects. The results from the flight trials showed the interference effects to be very sensitive to stick interval and that it could possibly be of a "step function" nature. The results also indicated that the mathematical simulation model to be developed must be capable of dealing with parameters such as release disturbance effects, weapon system timing, variations in bomb to bomb parameters, etc.

A summary of the flight trial releases is presented in table II.

WIND TUNNEL TRIALS

Basically, two distinct sets of wind tunnel data were available for analysis; isolated bomb data (i.e. infinite axial separation) and "in wake" bomb data. In the analysis of the data it was necessary to make an attempt to reduce the number of dependent variables (because of excessive table "look up" time in the mathematical model) by replacing them with empirical expressions. The other aspect of the data analysis was an attempt to see if the aerodynamic data could possibly explain the phenomena observed in flight trial releases. The sign convention for the aerodynamic coefficients together with geometric definitions are presented in figure 6.

Free-Stream Characteristics

For a symmetrical configuration the aerodynamic characteristics should be symmetrical for positive and negative incidences about their respective axes.

The "raw" values of drag area C_xS required only a small axial shift in order to obtain symmetry. The wind tunnel values of C_xS were scaled by a factor of 1.26 to match drag areas obtained from full scale flight trials. An empirical expression has been derived for the drag area in terms of incidence (α), the variation with Mach No. over the range tested was negligible. This expression is presented in figure 7.

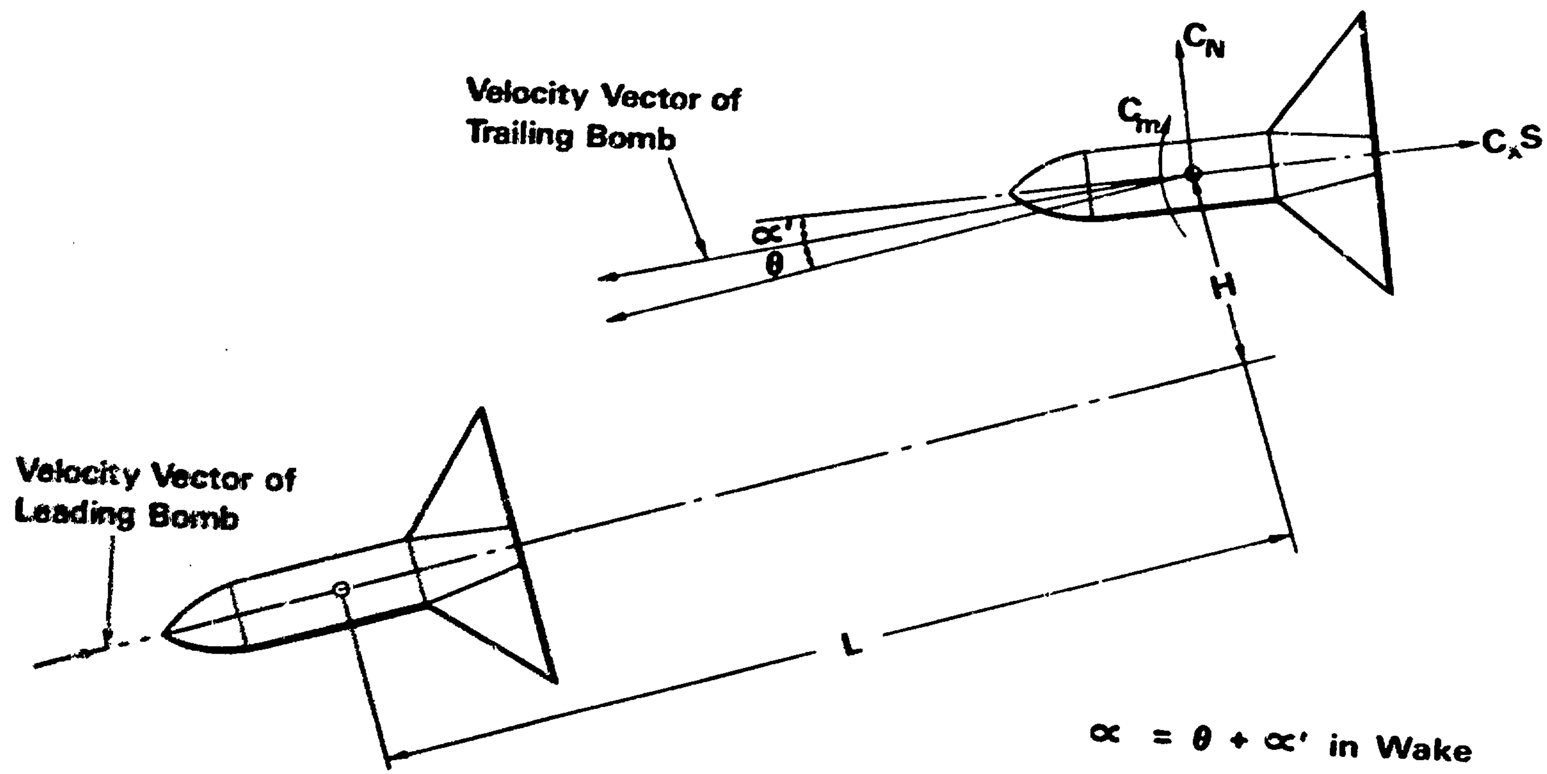
TABLE II SUMMARY OF TRIALS RELEASES OF THE RETARDED 1000LB M.C. BOMB FROM THE BOMB BAY OF THE BUCCANEER AIRCRAFT

TRIAL NO.	ST. NO.	STICK INTERVAL (secs)	RELEASE HEIGHT (AGL) (ft)	RELEASE SPEED (EAS) (kns)	EQUIVALENT EJECTION VELOCITY (ft/sec)	EQUIVALENT LATERAL VELOCITY (ft/sec)	RETARDER DEPLOYMENT TIME (secs)
1.1	5	0.141	537	445	-13.6	-0.8	0.890
1.2	6		538	445	-16.1	1.3	0.874
2.1	5	0.144	590	439	-16.0	-0.5	0.885
2.2	6		590	439	-16.0	1.0	0.864
3.1	5	0.146	516	447	-9.1	-1.8	0.916
3.2	6		515	447	-12.2	4.1	0.972
4.1	5	0.146	534	449	-15.7	-0.4	0.884
4.2	6		535	449	-16.0	0.8	0.870
5.1	5	0.144	516	445	-13.5	-1.2	0.903
5.2	6		515	445	-15.2	1.5	0.897
6.1	5	0.174	464	446	-9.9	-0.2	0.784
6.2	8		463	446	-15.5	-2.4	0.851
7.1	5	0.176	518	447	-11.7	-1.0	0.810
7.2	8		519	447	-14.5	-1.3	0.824
8.1	5	0.178	629	460	-10.8	0.2	0.900
8.2	6		628	460	-9.2	1.4	0.918
9.1	5	0.177	515	447	-9.2	-0.8	0.858
9.2	6		515	448	-9.1	0.8	0.839
10.1	5		567	453	-15.5	-0.6	0.830
10.2	8*	-	-	-	-	-	-

* Retarder failed to deploy

TABLE II SUMMARY OF TRIALS RELEASES OF THE RETARDED 1000LB M.C. BOMB FROM THE BOMB BAY OF THE BUCCANEER AIRCRAFT (continued)

TRIAL NO.	ST. NO.	STICK INTERVAL (secs)	RELEASE HEIGHT (AGL) (ft)	RELEASE SPEED (EAS) (kns)	EQUIVALENT EJECTION VELOCITY (ft/sec)	EQUIVALENT LATERAL VELOCITY (ft/sec)	RETARDER DEPLOYMENT TIME (secs)
11.1	5		528	448	-12.5	1.2	0.858
11.2	8	0.144	529	448	-12.5	1.5	0.872
12.1	5		538	453	-11.9	-1.6	0.817
12.2	8	0.144	538	453	-13.9	-5.6	0.839
14.1	5		504	444	-14.9	0.4	0.821
14.2	6	0.143	507	444	-11.2	0.1	0.843
15.1	5		534	452	-10.6	-3.2	0.792
15.2	6	0.142	535	449	-11.3	1.3	0.790
16.1	5		534	450	-10.4	-2.2	0.845
16.2	6	0.144	563	450	-15.7	-1.9	0.833
17.1	5		484	454	-13.2	3.1	0.780
17.2	6	0.152	484	454	-16.2	3.2	0.816
18.1	5		526	448	-14.4	-2.7	0.808
18.2	6	0.155	525	448	-15.5	-0.2	0.845
19.1	5		501	444	-13.5	0.5	0.826
19.2	6	0.151	501	444	-12.4	3.6	0.815



$\alpha = \theta + \alpha'$ in Wake

$\alpha = \alpha'$ not in Wake

Fig.6 Sign Convention and Axes System

$$C_x S = 22{\cdot}0 - \frac{2{\cdot}333}{(\alpha^2 + 1)^{1/2}}$$

$$C_N = K\left\{-0{\cdot}142 + 0{\cdot}126\left(1{\cdot}5 - \frac{1}{(1 + 0{\cdot}045|\alpha|)}\right)\Big||\alpha| - 2{\cdot}25\Big|\right\}$$

$$\alpha \geq 0^\circ \quad K = +1, \quad \alpha < 0^\circ \quad K = -1$$

$$C_m = -\alpha\left(0{\cdot}1932 + \frac{1{\cdot}172}{(|\alpha| + 1)}\right)$$

α ~ Degrees

Fig.7 Free-Stream Aerodynamic Coefficients

and graphically together with wind tunnel results in figure 8. The empirical expression provides an accurate representation of the tunnel results to within $\pm 1.5\%$.

Similarly the normal force C_N results required only a small axial shift to provide symmetry; the empirical expression assumed to be independent of Mach No. is presented in figure 7 and graphically in figure 9. Figure 9 shows the empirical expression to provide an accurate representation of the wind tunnel results.

The raw data for the pitching moment coefficient were puzzling in as much that at zero incidence a considerable positive moment existed. Whether this anomaly was due to apparent mass effects at high speed or model misalignments/oscillations is not known. However, whatever the cause, the raw C_m data were adjusted to be symmetrical about zero incidence. The empirical expression for this coefficient (assumed to be independent of Mach No.) is presented in figure 7 and graphically in figure 10. It can be seen that the empirical expression provides an accurate representation of the tunnel results.

Wake Characteristics

Measured forces and moments acting on the rear model bomb in the wake of the forward bomb are expected to have a lower order of accuracy compared to those obtained in free stream conditions. Basically these errors arise from

(i) Forward bomb oscillations

(ii) Turbulent wake effects

(iii) Bomb damage and oscillations.

Maximum errors are expected to occur for zero offset ($H = 0$) where maximum turbulence would be encountered. In general, the raw data for C_m reflect these errors to their maximum extent and a more detailed analysis of these results is necessary.

As in the free-stream analysis, large positive values of C_m were observed at zero incidence, the magnitude of these errors tending to decrease with increasing longitudinal separation. The raw data of $C_X S$, C_N and C_m at zero offset were adjusted to be symmetrical for positive and negative incidences. Any errors that may exist in the raw data for offsets other than zero cannot be estimated and consequently were left unadjusted. The only method of eliminating these possible errors would have been to obtain results for negative offsets (i.e. $H < 0$) and for the present test arrangement results for negative offsets would have included effects due to forward bomb mounting interference.

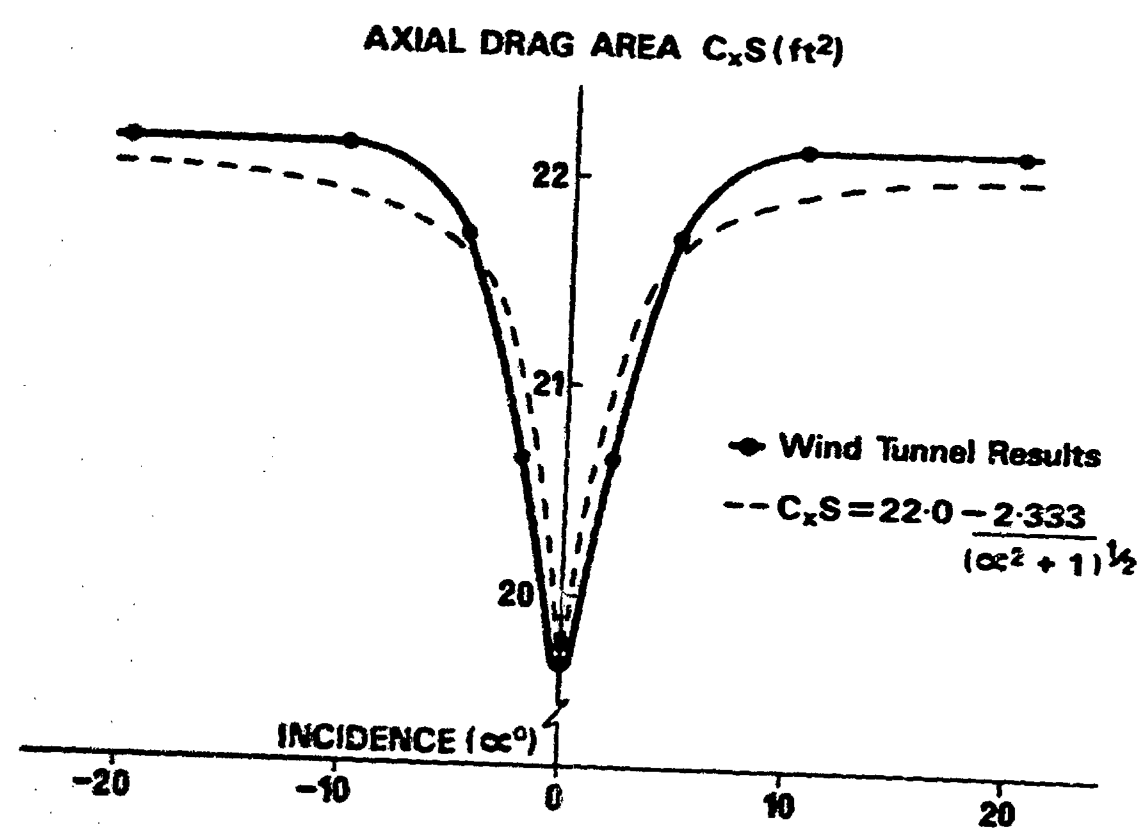
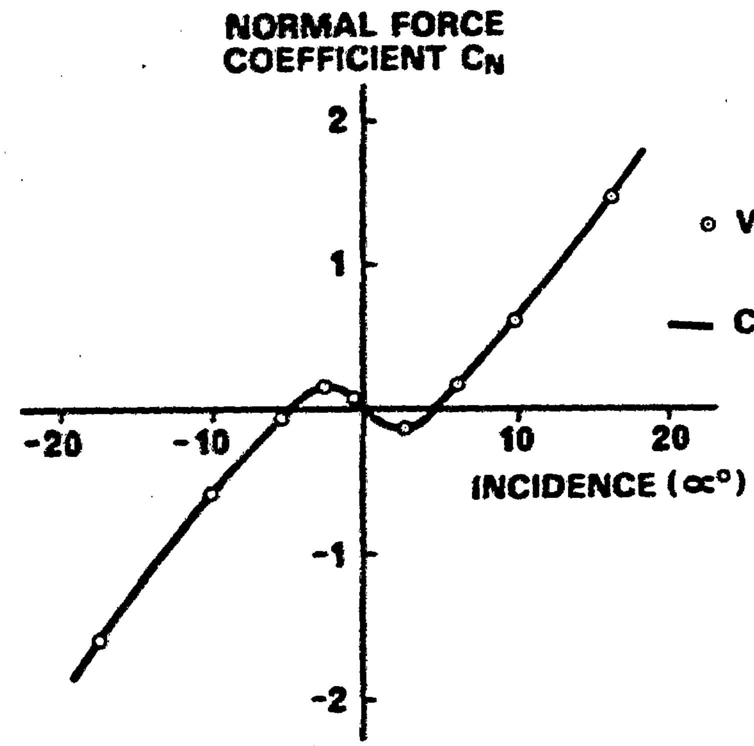


Fig.8 Comparison Between Wind Tunnel Results and Empirical Fit of Free-Stream Axial Drag Area Coefficient



○ Wind Tunnel Results

— $C_N = K\left\{-0.142 + 0.126\left(1.5 - \frac{1}{(1+0.045|\alpha|)}\right)\left||\alpha| - 2.25\right|\right\}$

$\alpha \geq 0°\quad K = +1,\quad \alpha < 0°\quad K = -1$

Fig.9 Comparison Between Wind Tunnel Results and Empirical Fit of Free-Stream Normal Force Coefficient

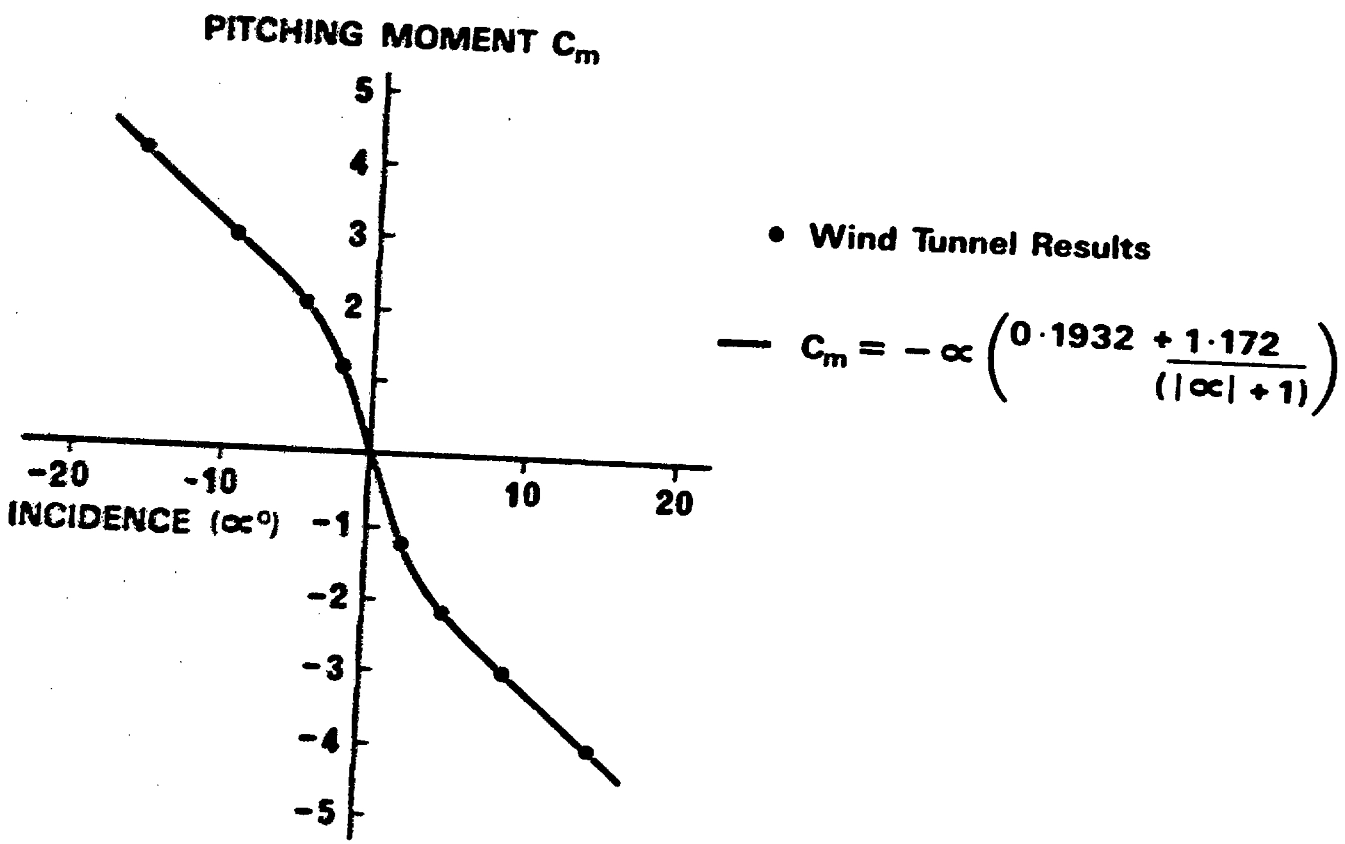


Fig.10 Comparison Between Wind Tunnel Results and Empirical Fit of Free-Stream Pitching Moment Coefficient

In order to reduce the amount of data input to the mathematical simulation model (developed concurrently with the analysis) empirical expressions have been derived thereby reducing the dimensions of "look up" tables.

The axial drag area coefficient $C_X S$ was the most amenable for reduction and the dependents Mach No., M and incidence α were replaced by an empirical expression, thereby reducing a 4-dimensional to a 2-dimensional table "look up". The empirical expression is presented in table III. A typical comparison of empirical expressions and the raw data (scaled by a factor of 1.26) are presented in figure 12. Although the empirical fits are not as accurate as those for the isolated bomb characteristics, the errors lie within $\pm 8\%$.

Because of the somewhat irregular behaviour of the normal force (C_N) and pitching moment (C_m) coefficients it has been possible to remove only one parameter, Mach No., by the substitution of empirical expressions thereby reducing the two 4-dimensional "look up" tables to two 3-dimensional tables. The empirical expressions are presented in figure 11 and the "look up" tables are presented in Tables IV and V. Graphical comparisons between empirical expressions and raw C_N and C_m data are presented in figures 13 and 14 respectively.

The tables present the exact raw data values of C_N and C_m for $M = 0.7$ and consequently the data presented graphically relate to $M = 0.7$. In general, the empirical expressions are less accurate at the high Mach No. of 0.8. As this loss of accuracy was unavoidable, it was decided that the majority of the inaccuracy should occur at the highest Mach No. tested.

Additional Remarks

The value of offset (H) is measured perpendicular from the velocity vector of the forward bomb and the centre of gravity of the rear bomb. This effectively implies that the attitude of the forward bomb does not adversely affect the wake characteristics. In view of the small amplitude oscillatory motion of the forward bomb (resulting from its very stable configuration) this assumption is thought to be justifiable.

An amount of uncertainty arises in the prediction of the effective wake boundary. The regions of this boundary may be estimated by examination of tables III, IV and V. At zero incidence the values of C_N and C_m should tend to zero as the offset (H) approaches the effective wake boundary. The tables indicate that at $H = 10.9$ body diameters (d) the coefficients tend to zero for all axial separations (L). Bearing in mind the turbulent nature of the wake and that no data is currently available for $H > 10.9d$, it was considered that the $L > 4\ell$ the effective wake boundary occurs at $H = \pm 10.9d$. For values of $L \leq 4\ell$ the wake boundary has been assumed to have the form of a tangent ogive and at $L = 0$, H has the value of D, the canopy diameter (see below).

$$H_W = -37.4 + (1880 - 53.8(L_{E/L})^2 + 430L_{E/L})^{\frac{1}{2}} \quad (ft) \tag{3}$$

$$\text{for } 0 \leqslant L_{E/L} \leqslant 4$$

$$H_W = 6 \text{ (ft) for } L_{E/L} > 4 \tag{4}$$

where H_W is radial offset of wake boundary (ft)

$L_{E/L}$ is number of body lengths separation between bombs (see figure 15)

No aerodynamic data are currently available for Mach Nos below 0.6. At these Mach Nos the bomb is in the incompressible flow regime and consequently the coefficients are assumed to correspond to those obtained at M=0.6. Extrapolation of data above M=0.8 is not recommended; the probability of operational use above this Mach No. is unlikely and when it does occur the high retardation experienced will reduce the Mach No. rapidly.

Typical examples of the wind tunnel results for the "in wake" axial force, normal force and pitching moment coefficients are presented in figures 12, 13 and 14 respectively. The data presented in these figures are for a Mach No. of 0.7 and an axial separation distance of 7 body lengths, and shows the variation of the coefficients with lateral offset and incidence. The important points to notice in figure 12 is how the drag reduces and the "hollow" at zero incidence disappears with decreasing lateral offset. It is therefore clear that in flight the rear bomb will have a reduced drag and will close relative to the forward bomb particularly if at a non-zero offset.

The significant curves are the pitching moment variation with incidence, offset and axial separation. Figure 14 shows the variation for an axial separation of 7 bomb lengths and shows how the pitching moment curve changes slope as offset distance decreases.

At relatively large offsets, the sense of the pitching moment is always stable (to reduce incidence), but as the offset reduces to a critical value which is associated with the canopy entering the edge of the wake, the pitching moment tends to become unstable. This instability results in an increase in bomb incidence together with an increase in lift force which is directed towards the wake central axis. In flight a form of "lock in" therefore takes place as the rear bomb approaches the wake centre. The pitching moment and lift force driving the bomb towards the centre of the wake reduce and reverse as the bomb moves into the other half of the wake. Meanwhile the rear bomb closes on the front bomb because of the reduction in drag, and collision between the bombs is almost inevitable.

TABLE III AXIAL DRAG AREA COMPONENT $C_x S'(H,L)_{M=0.7}$

L \ H	0	1.09d	2.18d	3.37d	4.36d	6.54d	8.72d	10.90d
4ℓ	13.10	15.80	17.17	20.21	21.35	21.55	21.42	21.42
5ℓ	14.11	16.07	18.90	20.54	21.52	21.67	21.48	21.42
6ℓ	16.13	17.11	18.21	19.74	21.32	22.05	21.92	21.80
7ℓ	18.64	17.92	18.65	19.87	20.95	22.39	22.30	22.30
9ℓ	17.64	17.85	18.14	19.09	20.16	21.55	21.74	21.74
$L = \infty$	21.99	21.99	21.99	21.99	21.99	21.99	21.99	21.99

H lateral offset, store diameters
d store diameter (ft)
L longitudinal separation store lengths
ℓ store length (ft)

TABLE IV NORMAL FORCE COEFFICIENT COMPONENT $C_N'(H, L\alpha)_{M=0.7}$

L	H	-15^o	-10^o	-5^o	0^o	$+5^o$	$+10^o$	$+15^o$
4ℓ	0	-1.94	-1.14	-0.55	0	+0.55	+1.14	+1.94
	2.18d	-2.97	-2.37	-1.77	-1.16	-0.56	0	+0.57
	4.36d	-2.28	-1.52	-1.03	-0.64	-0.25	+0.20	+0.88
	6.54d	-1.82	-1.15	-0.77	-0.28	+0.02	+0.53	+1.34
	8.72d	-1.45	-0.75	-0.45	-0.27	+0.11	+0.63	+1.47
	10.90d	-1.08	-0.35	-0.13	-0.10	+0.10	+0.68	+1.97
5ℓ	0	-1.97	-1.13	-0.50	0	+0.50	+1.13	+1.97
	2.18d	-2.95	-2.28	-1.68	-1.12	-0.55	+0.15	+0.85
	4.36d	-2.14	-1.62	-1.12	-0.62	-0.15	+0.48	+1.30
	6.54d	-1.91	-1.22	-0.80	-0.45	+0.05	+0.79	+1.65
	8.72d	-1.77	-0.87	-0.57	-0.36	+0.11	+0.82	+1.64
	10.90d	-1.63	-0.52	-0.34	-0.25	+0.11	+0.84	+1.66
6ℓ	0	-1.81	-1.01	-0.47	0	+0.47	+1.01	+1.81
	2.18d	-2.56	-1.90	-1.34	-0.80	-0.20	+0.35	+0.95
	4.36d	-2.34	-1.78	-1.13	-0.75	-0.38	+0.20	+0.96
	6.54d	-1.95	-1.21	-0.80	-0.45	-0.10	+0.65	+1.52
	8.72d	-1.62	-0.82	-0.52	-0.40	+0.05	+0.73	+1.55
	10.90d	-1.29	-0.44	-0.24	0.0	+0.05	+0.77	+1.59
7ℓ	0	-1.28	-0.70	-0.30	0	+0.30	+0.70	+1.28
	2.18d	-1.65	-1.06	-0.65	-0.37	+0.05	+0.40	+0.93
	4.36d	-1.78	-1.20	-0.71	-0.35	-0.02	+0.31	+0.88
	6.54d	-1.50	-0.91	-0.50	-0.17	-0.10	+0.50	+1.12
	8.72d	-1.18	-0.58	-0.28	-0.17	+0.08	+0.63	+1.25
	10.90d	-0.86	-0.25	-0.06	-0.05	+0.08	+0.68	+1.30
8ℓ	0	-1.59	-0.89	-0.40	0	+0.40	+0.89	+1.59
	2.18d	-1.97	-1.22	-0.74	-0.33	+0.05	+0.53	+1.19
	4.36d	-2.02	-1.35	-0.82	-0.45	-0.10	+0.38	+1.04
	6.54d	-1.70	-1.06	-0.58	-0.30	-0.05	+0.52	+1.29
	8.72d	-1.50	-0.86	-0.36	-0.21	+0.13	+0.68	+1.41
	10.90d	-1.30	-0.66	-0.14	-0.11	+0.18	+0.77	+1.50
∞	0	-1.28	-0.64	-0.05	0	+0.05	+0.64	+1.28
	2.18d	-1.28	-0.64	-0.05	0	+0.05	+0.64	+1.28
	4.36d	-1.28	-0.64	-0.05	0	+0.05	+0.64	+1.28
	6.54d	-1.28	-0.64	-0.05	0	+0.05	+0.64	+1.28
	8.72d	-1.28	-0.64	-0.05	0	+0.05	+0.64	+1.28
	10.90d	-1.28	-0.64	-0.05	0	+0.05	+0.64	+1.28

TABLE V PITCHING MOMENT COEFFICIENT COMPONENT $C_m'(H,L,\alpha)_{M=0.7}$

L	α° / H	-15°	-10°	-5°	0	$+5^\circ$	$+10^\circ$	$+15^\circ$
4ℓ	0	+3.40	+2.35	+1.50	0	-0.65	-2.35	-3.40
	2.18d	+6.90	+6.00	+5.15	+4.30	+3.10	+1.60	+0.90
	4.36d	+4.90	+4.08	+3.32	+2.70	0	-1.07	-1.97
	6.54d	+4.50	+3.40	+2.90	+1.82	-1.27	-2.17	-3.38
	8.72d	+4.40	+3.30	+2.52	+1.05	-1.45	-2.35	-3.48
	10.90d	+4.30	+3.20	+2.14	+0.70	-1.50	-2.35	-3.48
5ℓ	0	+3.70	+2.25	+0.93	0	-0.93	-2.25	-3.73
	2.18d	+6.70	+5.75	+4.80	+4.00	+2.70	+0.90	-0.30
	4.36d	+4.55	+3.85	+2.80	+1.75	+0.05	-1.75	-3.10
	6.54d	+4.60	+3.50	+2.57	+0.05	-1.50	-2.57	-4.10
	8.72d	+4.60	+3.50	+2.50	+0.65	-1.50	-2.80	-4.14
	10.90d	+4.60	+3.50	+2.43	-0.40	-1.60	-2.80	-4.14
6ℓ	0	+3.10	+1.87	+0.80	0	-0.80	-1.87	-3.10
	2.18d	+5.70	+4.74	+3.80	+2.80	+1.50	+0.25	-1.00
	4.36d	+5.20	+4.28	+3.50	+2.80	+0.05	-0.58	-1.67
	6.54d	+4.50	+3.50	+2.92	+1.35	-1.19	-2.20	-3.67
	8.72d	+4.40	+3.40	+2.70	+0.25	-1.47	-2.54	-4.03
	10.90d	+4.30	+3.30	+2.48	0	-1.50	-2.64	-4.13
7ℓ	0	+2.60	+1.68	+0.76	0	-0.76	-1.68	-2.60
	2.18d	+4.10	+3.10	+2.62	+1.80	+0.60	-0.40	-1.20
	4.36d	+4.58	+3.72	+3.00	+2.30	+0.90	-0.27	-1.08
	6.54d	+3.95	+3.00	+2.50	+1.60	-0.70	-1.50	-2.40
	8.72d	+3.75	+2.70	+2.12	+1.05	-1.15	-2.07	-3.10
	10.90d	+3.55	+2.40	+1.74	+0.55	-1.28	-2.15	-3.22
8ℓ	0	+3.31	+2.17	+1.12	0	-1.12	-2.17	-3.31
	2.18d	+4.48	+3.45	+2.55	+1.40	0	-1.35	-2.15
	4.36d	+4.93	+3.97	+3.10	+2.07	+0.10	-0.98	-1.73
	6.54d	+4.34	+3.24	+2.60	+1.32	-1.00	-1.78	-2.97
	8.72d	+4.00	+2.90	+2.40	+0.20	-1.48	-2.43	-3.62
	10.90d	+3.66	+2.56	+2.10	-0.25	-1.65	-2.55	-3.74
∞	0	+3.95	+3.00	+2.10	0	-2.10	-3.00	-3.95
	2.18d	+3.95	+3.00	+2.10	0	-2.10	-3.00	-3.95
	4.36d	+3.95	+3.00	+2.10	0	-2.10	-3.00	-3.95
	6.54d	+3.95	+3.00	+2.10	0	-2.10	-3.00	-3.95
	8.72d	+3.95	+3.00	+2.10	0	-2.10	-3.00	-3.95
	10.90d	+3.95	+3.00	+2.10	0	-2.10	-3.00	-3.95

$$C_x S\left[M,H,L,\alpha\right] = S\,C_x S'\left[H,L\right]_{M=0\cdot7} - \frac{25\cdot2\,\mathrm{Sin}^2(1\cdot837\,H)}{(\alpha^2+1)^{1/2}} + 1\cdot26\,F\,(0\cdot4 - 0\cdot0918\,H).$$

$$C_N\left[M,H,L,\alpha\right] = C_N'\left[H,L,\alpha\right]_{M=0\cdot7} - F\,(0\cdot01\alpha - 0\cdot05).$$

$$C_m\left[M,H,L,\alpha\right] = C_m'\left[H,L,\alpha\right]_{M=0\cdot7} - F\left(0\cdot2 - (\alpha + |\alpha|)\,0\cdot02\right).$$

$$\text{where } \begin{array}{ll} F = (7-10M) & M \geq 0\cdot6 \\ F = 1 & M < 0\cdot6 \end{array}$$

$C_x S'\left[H,L\right]_{M=0\cdot7}$ ———— Table III

$C_N'\left[H,L,\alpha\right]_{M=0\cdot7}$ ———— Table IV

$C_m'\left[H,L,\alpha\right]_{M=0\cdot7}$ ———— Table V

$$X = \tfrac{1}{2}\rho V^2 C_x S\left[M,H,L,\alpha\right].$$

$$N = \tfrac{1}{2}\rho V^2 C_N S\left[M,H,L,\alpha\right].$$

$$M = \tfrac{1}{2}\rho V^2\, d\, C_m S\left[M,H,L,\alpha\right].$$

Fig.11 Wake Aerodynamic Coefficients

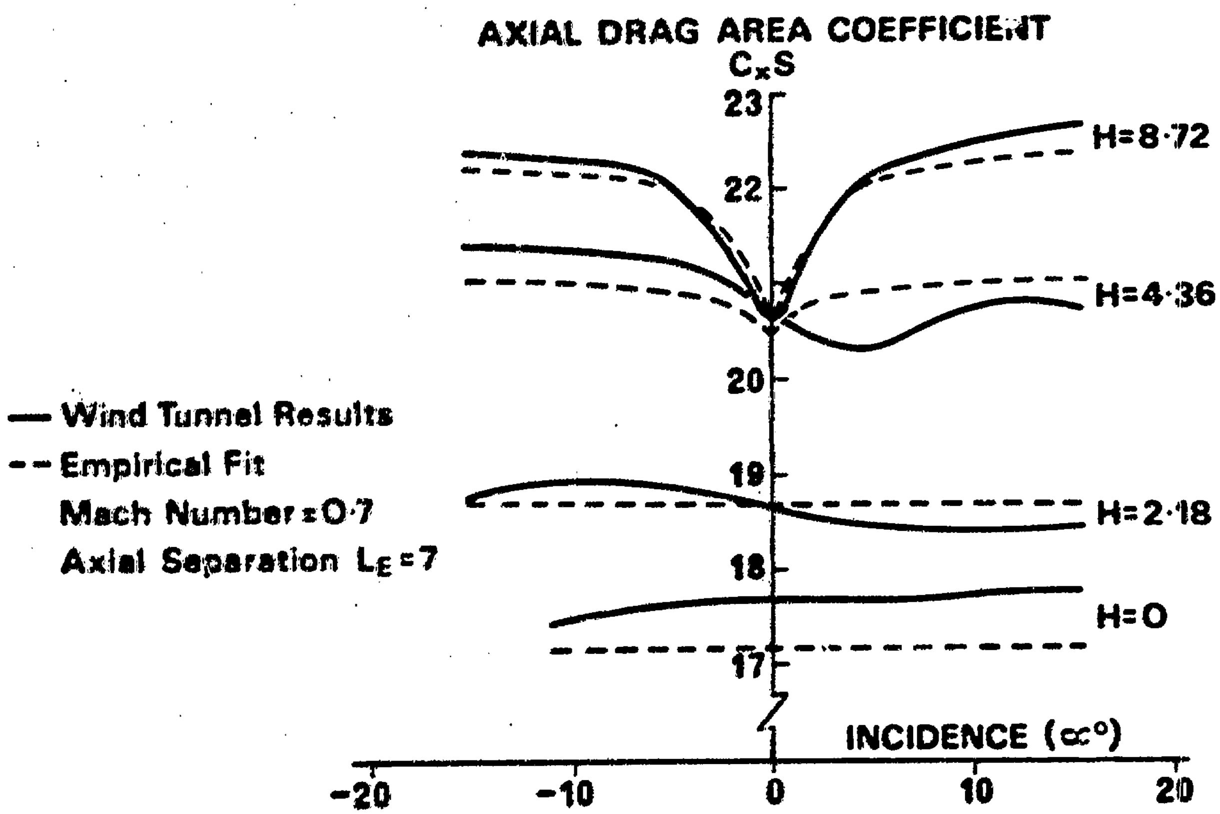


Fig.12 Comparison Between Wind Tunnel Results and Empirical Fit of Wake Axial Force Coefficient

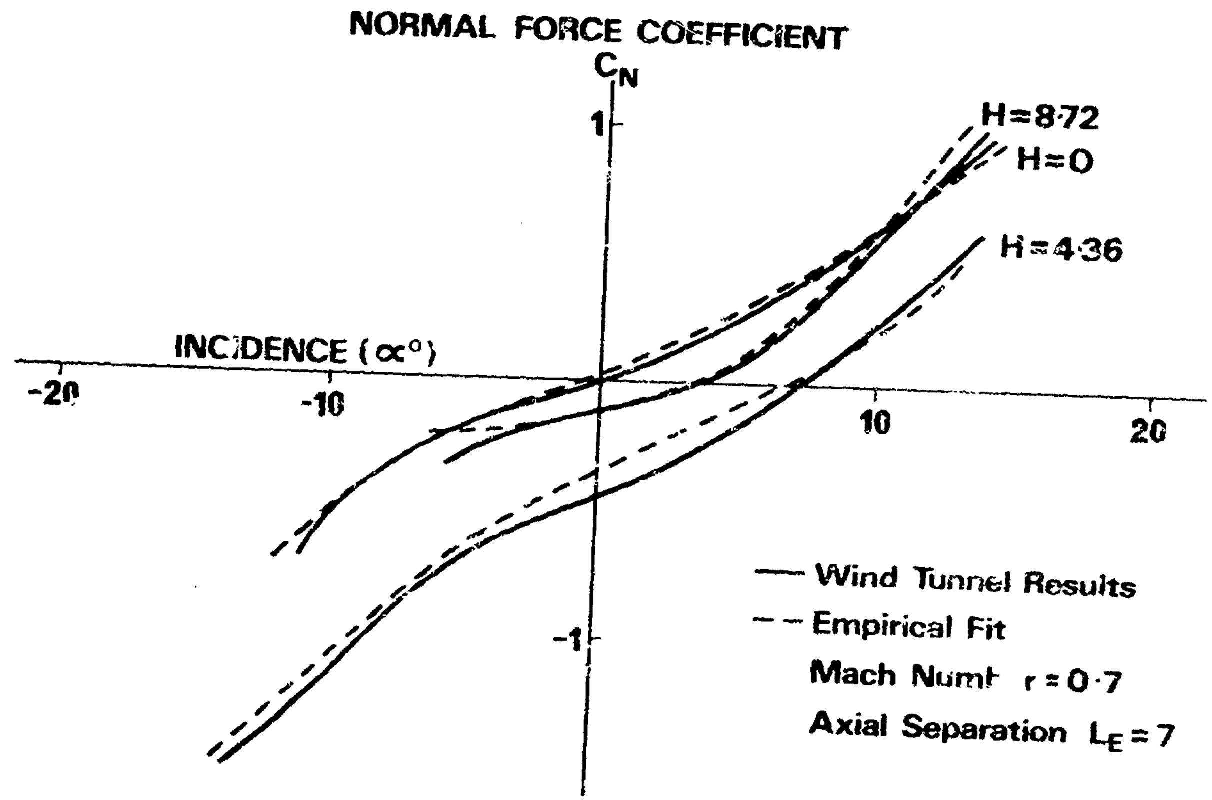


Fig.13 Comparison Between Wind Tunnel Results and Empirical Fit of Wake Normal Force Coefficient

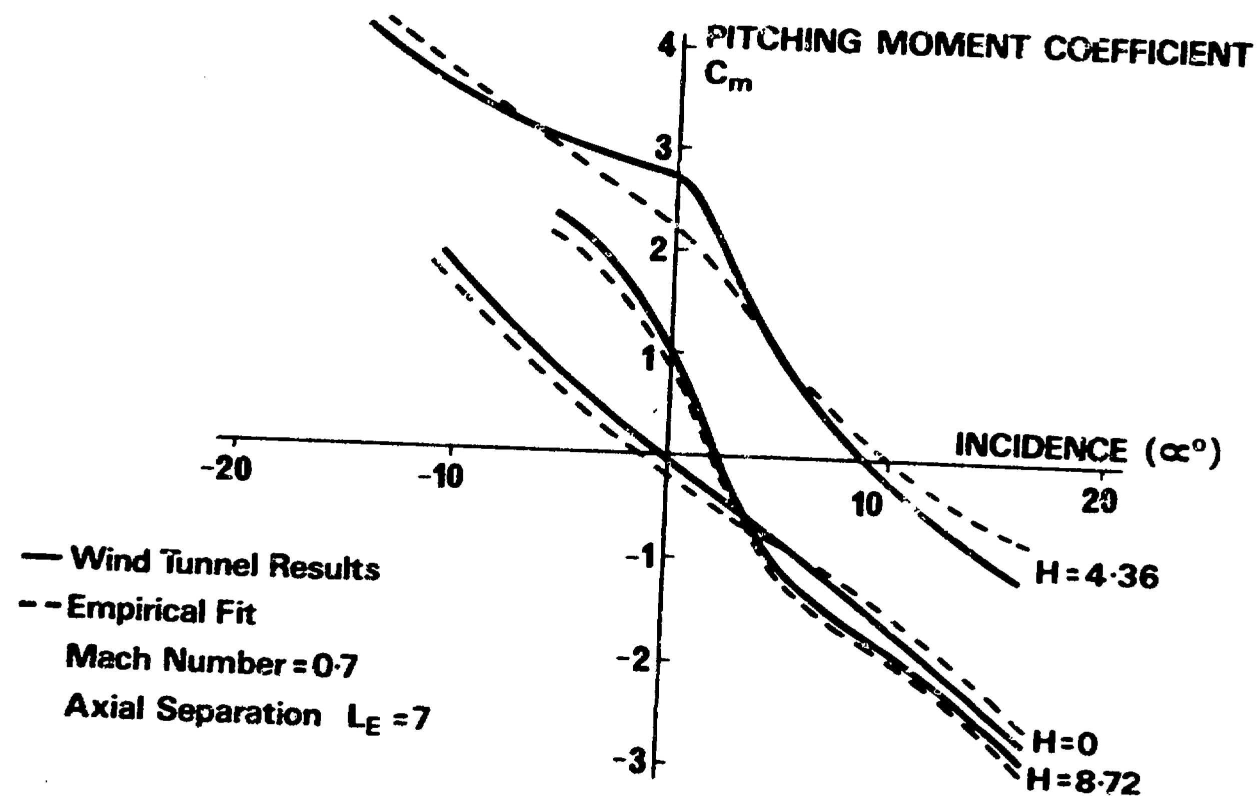


Fig.14 Comparison Between Wind Tunnel Results and Empirical Fit of Wake Pitching Moment Coefficient

Examination of the basic wind tunnel data has allowed the above motion of the rear bomb to be derived, subsequently the mathematical model will be used to demonstrate this motion, which is typical of that observed under certain conditions in flight trials.

MATHEMATICAL MODEL

Aerodynamic data obtained from the tandem wind tunnel tests were restricted to the plane containing the longitudinal axes of the two bombs and the incidence plane of the rear bomb. Consequently, it was necessary to consider a 3-Degree of Freedom mathematical model to investigate the interference effects between the two bombs. The equations of motion representing this type of motion are of the standard form and therefore do not justify discussion here. However, the wake characteristics are of a more complex nature and are discussed below.

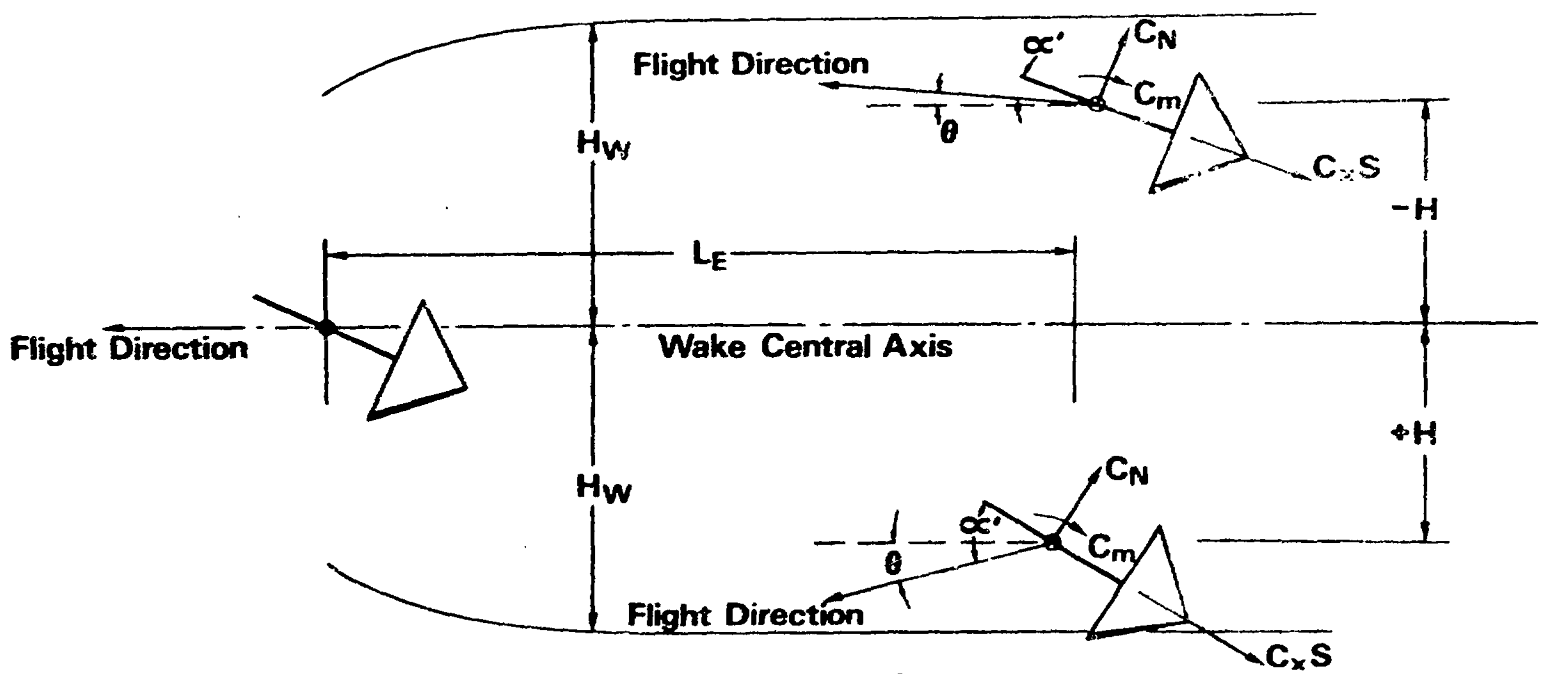
WAKE MODEL

The wake emanating from the forward bomb is assumed to be enclosed within a physical boundary that is symmetrically distributed about the flight path of the forward bomb. This inherently assumes that the local angle of incidence of the forward bomb to its flight path does not significantly alter the wake characteristics. In view of the small amplitude oscillation achieved by the highly stable forward bomb, this is considered to be a reasonable assumption. The physical wake boundary is presented in figure 15. As the program determines the relative locations of the centres of gravity of the bombs, the effective wake boundary is defined as the addition of the physical wake boundary and a canopy radius (i.e. if $H \leq H_W + R$ then the rearward bomb is considered to be in the wake of the forward bomb).

WAKE INTERFERENCE

This paragraph describes the manner in which the "in wake" aerodynamic data are selected and used in determination of the overall forces and moments.

To reduce the amount of "look up" data mirror image symmetry about the wake central axis has been assumed. Wind tunnel data for the rear bomb was restricted to the upper section of the wake only (negative H as shown in figure 15), positive incidence being nose up. In the upper section of the wake the incidence is considered to be the angle between the rear bomb longitudinal axis and the wake central axis ($\alpha = \alpha' + \theta$, see figure 15). Clearly, if the bomb has the same spacial positive incidence but is in the lower section of the wake (positive H as shown in figure 15) it is necessary to consider the incidence to be negative, use the "look up" tables and finally reverse the signs of the normal force and pitching moment coefficients obtained.



$$H_W = -37{\cdot}4 + \left[1880 - 53{\cdot}8\,(L_E/L)^2 + 430\,(L_E/L)\right]^{1/2}; \quad 0 \leq L_E/L \leq 4.$$

$$H_W = 6 \qquad L_E/L > 4. \qquad \alpha = \alpha' + \theta.$$

Fig.15 Wake Axes System and Body Aerodynamic Coefficient Notation

As the wind tunnel data are measurements of the mutual interference characteristics between two relatively stationary bombs, it is necessary to explain the procedure used in this program when a differential velocity exists. The aerodynamic coefficients for the rear bomb are found from the "look up" tables using the Mach No. of the forward bomb, the incidence of the rear bomb (i.e. the angles between the rear bomb longitudinal axis and the forward bomb instantaneous flight path), the lateral offset and the longitudinal offset. The forces and moments are then derived using the velocity of the rear bomb and free stream parameters. Although it is conceded that loss of accuracy may be introduced by using this method, it is likely to be small compared with the loss in accuracy due to the errors in the wind tunnel data.

MODEL LIMITATIONS

As the amount of aerodynamic data is limited it has been necessary to extrapolate the range of some of the coefficient dependents within the program. The Mach Nos. at which coefficients were derived were 0.6, 0.7 and 0.8. The data reduction, described earlier, necessitated a loss of accuracy of the wake coefficients for $M=0.8$. Whilst the program will extrapolate data for $M>0.8$, it is evident that a considerable loss of accuracy in the determination of the coefficients may be incurred. However, this loss of accuracy will occur for only a short period of the total flight time as the retardation during this period will be large. For $M<0.6$ the bomb is considered to be in the incompressible flow regime and consequently the coefficients are found by using the "look up" tables for $M=0.6$. The incidence range for which data are known is $\pm 15^{\circ}$. The program will extrapolate the incidence range to $\pm 50^{\circ}$ beyond which the program will be terminated.

The longitudinal separation range over which measured wake interference characteristics are available is from $L = 4\ell$ to $L = 9\ell$. It is apparent at $L = 9\ell$ the data are tending towards those obtained for free stream conditions. An arbitrary separation distance of $L = 20\ell$ at which the data reach free stream conditions has been incorporated into the program. For separation distances less than $L = 4\ell$, the shape of the wake boundary is assumed to be that of a tangent ogive (see figure 15) and within this region aerodynamic data are unknown. The program, however, determines the data in this region assuming that they correspond to those for $L = 4\ell$; the value of H used is determined by factorising the physical offset (i.e. distance between flight direction of forward bomb and the nearest extremity of the canopy of the rearward bomb) by 15/[illegible]$_W$.

It is probable that the rigid wake boundary assumed to be generated at the instant of retarder deployment will not truly represent the actual. This boundary and the data therein, will be influenced by oscillations of the forward bomb. In the absence of further data the maximum wake boundary is defined by the extreme lateral offset tested.

Provision has also been made in the program for the input of store carriage loads and local flow field effects when they became available.

Under some circumstances, the rear bomb can lie within the wake of the forward bomb at the instant of deployment of the forward bomb. When this situation occurs, the rear bomb experiences an instantaneous change in effective incidence which can be so rapid such that the numerical integration procedure can become "unstable".

MATHEMATICAL MODELLING

INITIAL SIMULATIONS

Data available from the initial flight trials Nos 1 - 12 related to situations where either severe or little interference between bombs occurred. Releases where severe interference occurred were considered not suitable for simulation purposes and effort was concentrated on simulating the other trials. As a typical example of the simulations, the results of trial number 9 are discussed.

For trial number 9 the "stick" interval between bombs released from stations 5 and 6 in the Buccaneer bomb bay was 0.177s. The longitudinal and lateral separations between bomb centre of gravity positions were 8ft and 2ft respectively, bomb 1 being forward of bomb 2. Currently, because of aerodynamic data limitations, the simulation model is restricted to a single plane, thus the lateral separation was ignored in this simulation. Although the nominal ejection velocities of the bombs were known from available data, the actual equivalent ejection velocities are dependent upon local flow field effects around the bomb bay. Although the simulation model is capable of accepting flow field effects they are not currently known for this environment. However, analysis of the kinetheodolite data allowed equivalent ejection velocities to be derived for each bomb such that their relative spacial positions at retarder deployment were correct. The velocities for the 1st and 2nd bombs released were 14.25 and 13.45ft/sec. respectively. Also associated with each bomb were initial nose down pitch rates of 0.6 radians/sec.

Comparing the interference free bomb trajectories, the predicted forward range is 2640ft., the corresponding trial result was 2590ft. The flight trial results also show a lateral drift of 110ft indicating significant wind effects which may account for the discrepancy in range values. The nominal difference between ground impact positions of the two bombs, associated with the aircraft release parameters should have been 124ft., the observed positions were separated by 80ft. Using the simulation model a difference in ground impact positions of 87ft was predicted indicating that 30% reduction due to wake effects ("capture") had occurred.

The simulation showed for this example, that at the instant of deployment of the 2nd bomb, the 1st bomb was vertically below it and subsequently moved into the wake of bomb 2. When the 1st bomb enters the wake the predicted longitudinal separation was $L_E = 0.7\ell$ and when it finally leaves the wake $L_E = 6.1\ell$. It is therefore evident that for the major part of the "in wake" trajectory the aerodynamic characteristics of the 1st bomb are obtained from severe extrapolations of wind tunnel data. Clearly, for this example, the good agreement obtained between predicted and trial results indicates the wake boundary and internal wake characteristics within this separation range to have been accurately defined.

FINAL SIMULATIONS

As previously stated trials Nos. 14 - 19 were conducted with nominal stick intervals intermediate to those used in trials Nos. 1 - 12.

In trials Nos. 15 and 16 severe interference between bombs was observed, whilst in trial No. 14 only a small amount of interference was observed. Of these trials, Nos. 14 and 15 were interesting as they had similar ejection velocities, stick intervals, retarder deployment and inflation times, yet trial No. 14 showed little interference and No. 15 showed severe interference. Examination of kinetheodolite data showed that for trial No. 14 the aircraft had a relatively large component of vertical velocity (+18.5ft/sec) at bomb release.

To simulate these trials using the mathematical model it was necessary to determine the correct spacial attitude of the bombs at release; for each bomb this was assumed to be along the flight path of the aircraft as the aircraft's incidence to its own flight path was not known. The simulation results are shown in figures 16 and 17 for trials Nos. 14 and 15 respectively, and confirm the aircraft rate of climb to dramatically influence the subsequent relative motion of the two bombs and must therefore be considered as another variable within the system. The computed ground spacing between the two bombs showed good agreement (105ft c.f. 110ft).

Of the remaining trials (Nos. 17, 18 and 19) only No. 19 proved to be amenable to a complete analysis. Attempts were made to simulate the releases in trial No. 17, however the simulations indicated a large degree of "capture" between bombs which was not observed in the trial. Analysis of the kinetheodolite data showed a lateral spacing between bombs at retarder deployment of 8ft. This lateral separation, which cannot currently be simulated by the model is the reason why no "capture" was predicted. The trajectory data obtained for the 2nd bomb, which receives no wake interference was simulated. The results obtained confirmed the adequacy of the model for simulating interference free bomb trajectories.

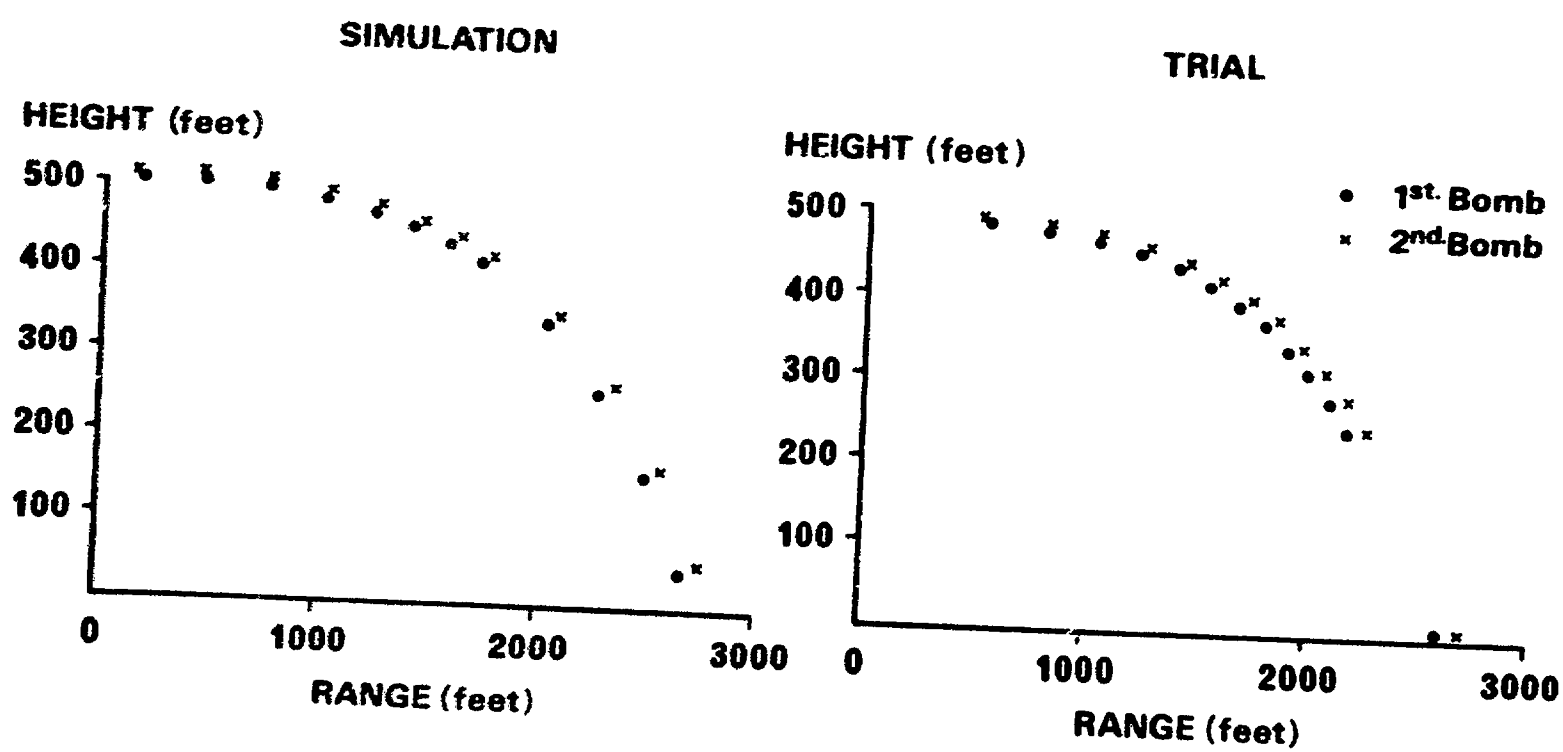


Fig.16 Comparison of Simulated and Trial Trajectories of Trial No.14

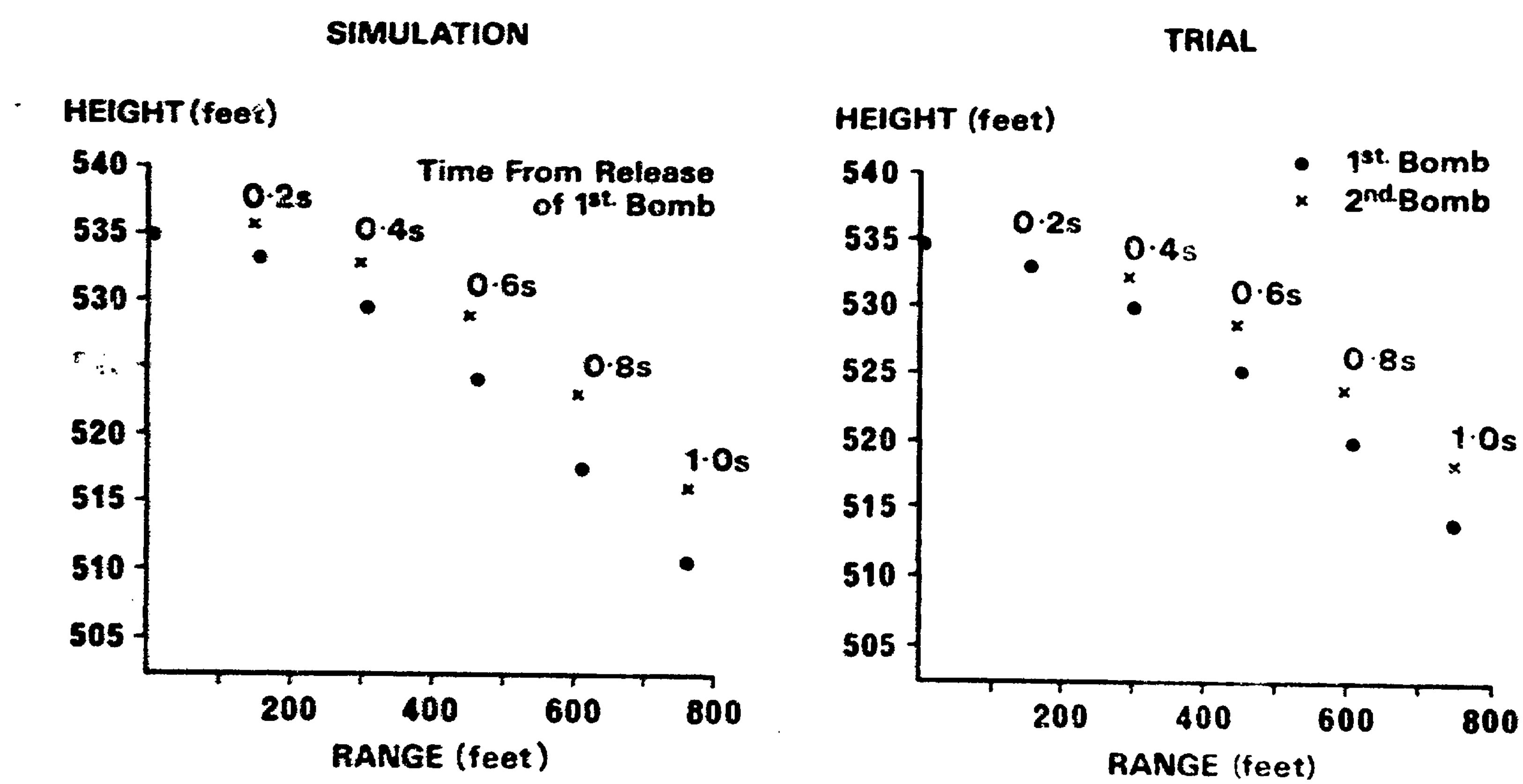


Fig.17 Comparison of Simulated and Trial Trajectories of Trial No.15

The most interesting trial from the interference viewpoint was trial No. 19, where both bombs were observed to impact in similar positions suggesting complete "capture". The simulation of the trajectories of the two bombs for this trial also indicated a significant amount of "capture", the trial and simulated trajectories being presented in figure 18. Kinetheodolite data for the trial shows that collision between the two bombs had not occurred before impact. However, the separation between the bombs was decreasing, suggesting that if the release height had been greater collision would ultimately have occurred. The results of the simulations confirmed the kinetheodolite results.

COMMENTS

Using the measured aerodynamic data in the mathematical model to simulate the flight trials has generally produced very good comparisons for a wide range of initial conditions. It is therefore concluded that the mathematical model developed to simulate the wake interference effects between pairs of retarded 1000lb bombs has been validated.

The model has been used to illustrate the behaviour of the rearward bomb whilst in the wake of the forward bomb. Assuming the ejection velocities of both bombs to be 14 ft/sec, the deployment times to be 0.84secs. and the stick interval to be 0.160secs, a condition for complete "capture" was defined. The results of this simulation are presented in figure 19. This figure shows that the rear bomb (the 1st bomb released) moves into the lower section of the wake of the forward bomb with the longitudinal separation increasing, is "captured" into the upper section of the wake, the differential velocity decreasing as the bomb moves across the wake central axis, and finally closes up on the forward bomb. The effective "build up" of incidence of the rear bomb is such that at 6.6 seconds it exceeds the bounds of the program ($>50^0$) and collision between the two bombs is unavoidable. This type of motion of the rear bomb as it approaches the forward bomb simulates the type of motion that has been observed in flight trials and previously predicted from examination of the wind tunnel results.

The simulation also demonstrates that under certain release conditions the interference effects between the two bombs is of a malignant nature and ultimate collision is unavoidable.

CONCLUSIONS

The experimental data obtained together with the theoretical studies completed have considerably increased the understanding of the mechanism of mutual retarder wake interference effects between pairs of retarded 1000lb bombs.

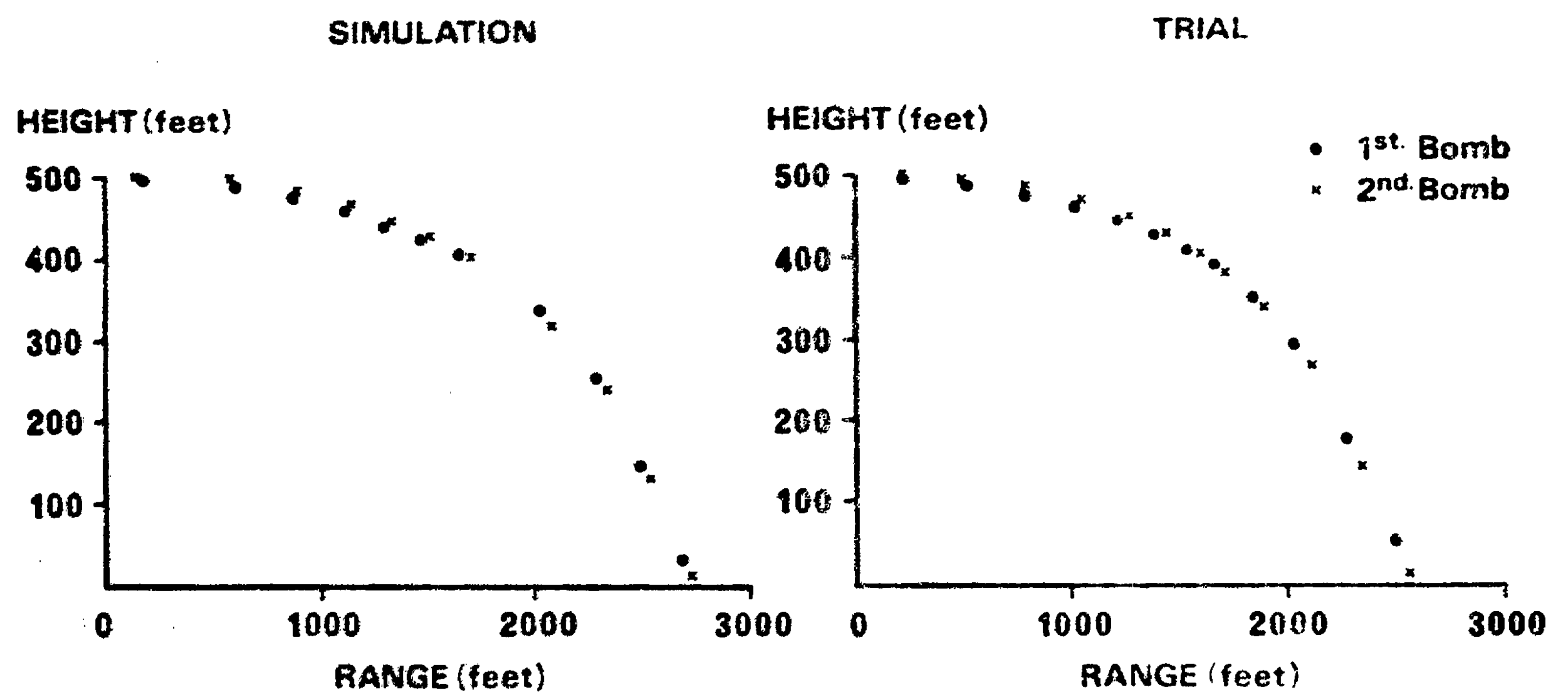


Fig.18 Comparison of Simulated and Trial Trajectories of Trial No.19

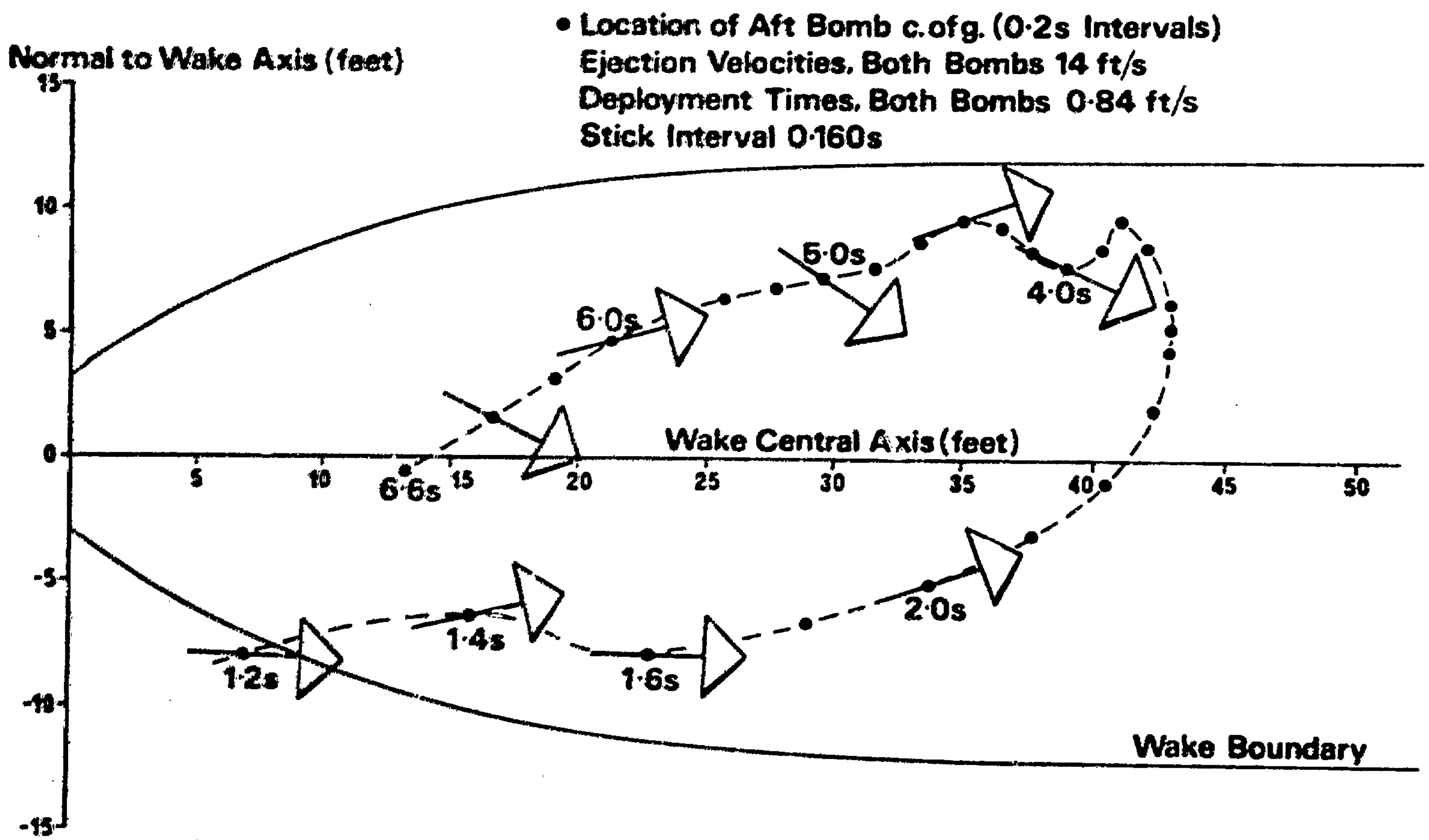


Fig.19 Typical Wake Motion

Flight trials conducted during the study have indicated that mutual interference between pairs of bombs to be extremely sensitive to "stick" spacing and aircraft conditions at release.

Wind tunnel data obtained from tests of a tandem pair of model bombs has confirmed the possibility of "capture" between bombs, as observed in flight trials, and under certain circumstances the "capture" can be of a malignant nature.

A 3-Degree of Freedom computer simulation model has been developed and using the wind tunnel data for simulation of flight trials good agreement has been achieved, thus indicating its validity.

The simulation model considers only two bombs and restricts their motion to a single plane. Developments are currently in progress extending the motion of the bombs to two planes.

Studies in progress using the simulation model and wind tunnel data are currently orientated towards showing the effect of carriage loads and moments and their decay with distance below the aircraft, on the mutual interference problem.

LIST OF ABBREVIATIONS

C_xS	Axial drag area coefficient
C_xS'	Component of axial drag area coefficient (Table III)
C_m	Pitching moment coefficient
C_m'	Component of pitching moment coefficient (Table IV)
C_N	Normal force coefficient
C_N'	Component of normal force coefficient (Table V)
d	Store diameter (1.375ft)
H	Distance of rear bomb centre of gravity from wake axis (Figure 6)
H_W	Distance of physical wake boundary from wake axis
ℓ	Store length (7.33ft)
L_E	Longitudinal separation between bombs (Figure 6)
M	Mach number
R	Canopy radius (3.0ft)
S	Store reference area ($\pi d^2/_4$ = 1.4849 ft^2)
V	Velocity
α'	Effective incidence
α	Total incidence in wake ($\alpha = \theta + \alpha'$, Figure 6)
θ	Flight path angle relative to wake axis (Figure 6)
θ_c, θ_s	Angles defining store position in wind tunnel (Figure 4)
ρ	Air density
[ ]	A function of
| |	Modulus of

AUTOBIOGRAPHY

Graduated from London University in 1961 with an honours degree in aeronautical engineering, specialising in aerodynamics and flight dynamics. On graduating, joined English Electric Aviation (G.W. Division) to work on the aerodynamic assessment of various types of missile configurations. In 1963 joined Hunting Engineering Limited as an aerodynamicist to work on the problems of unguided weapon systems. Appointed Chief Aerodynamicist of company in 1970 and Head of System Assessment in 1975.

Experience gained since joining Hunting Engineering covers many types of weapon systems including cluster munitions, retarded stores, high acceleration rockets, parachute payload dynamics and weapon/aircraft ballistics. Over the past two years also gained experience of the operational requirements for new weapon systems.

Currently an Associate Fellow of the Royal Aeronautical Society (A.F.R.Ae.S.) and seeking sponsorship for membership to the American Institute of Aeronautics and Astronautics (A.I.A.A.).

ACKNOWLEDGEMENT

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THE EFFECTS OF MODEL STORE DISTORTION ON RELEASE DISTURBANCE

by

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ABSTRACT. In the simulation of full-scale release of stores in the wind tunnel using a captive store trajectory system errors can arise due to the presence of the supporting sting and the consequent distortion of the rear end of the model. A boat-tail bomb has been tested at 1/5 scale in the wind tunnel with various after body distortions similar to those needed to accommodate a sting on a smaller 1/12 scale CTS model. A range of tail spans have also been tested to see whether a store design could be found with aerodynamic properties akin to those of the orginal store. A comparison is made of the aerodynamic characteristics and it is shown that the requirements for matching the longitudinal, lateral and rolling derivatives are all different.

Measurements were then made of the in-carriage loads on a 1/12 scale model store on the inboard shoulder of a triple carrier carried on the inboard pylon of a F4K aircraft, using an internal balance supported through the carrier. The effects of after body distortion and of the presence of the sting were also measured. Noticeable differences were observed particularly in the yawing moment. Some tests were also made to investigate the effect on a measured load of small variations in the detailed design of the aircraft installation which show that quite large changes in carriage loads can arise from small geometrical changes.

The significance of errors in the aerodynamic representation of a store can only be assessed by considering their effect on the store release disturbance and trajectory. Hence, theoretical estimates are made of the effect of model distortion on the trajectory of the store for a given release condition.

ILLUSTRATIONS

Figure

NOMENCLATURE

C_ℓ	Rolling-moment coefficient for store, positive stb side down rolling moment/qSd.
C_m	Pitching-moment coefficient for store, positive nose up pitching moment/qSd.
C_n	Yawing moment coefficient for store, positive nose inwards or nose to starboard; yawing moment/qSd.
C_N	Normal force coefficient for store, positive upwards normal force/qS.
C_y	Side force coefficient for store, positive inwards or to stb side force/qS.
d	Maximum diameter of store.
M	Free-stream Mach number.
S	Maximum cross-section of store, $\pi d^2/4$.
α_p	Incidence angle of parent aircraft, degrees.
α_s	Incidence angle of store, degrees.
β_p	Sideslip angle of parent aircraft, degrees.
δ	Increment compared with undistorted store.
θ_s	Pitch angle of store, degrees.
ϕ_s	Roll angle of fin of store from vertical, degrees.
ψ_s	Yaw angle of store, degrees.
014	Undistorted store.
112, 113, 114 214 314	Distorted stores - see figure 1.
114 S	Distorted store in presence of dummy sting.

INTRODUCTION

In the UK we have been evaluating the significance of possible sources of error in the design and use of captive store trajectory systems, prior to making a rig of our own for use in the 8' x 9' transonic wind-tunnel at ARA and the 8' x 8' subsonic/supersonic tunnel at RAE. This size of working section permits us to test at about 8% scale and inevitably distortions to accommodate the support sting will arise on stores with a small base area. Hence wind-tunnel tests have been made, firstly to determine the effects of these distortions and secondly, to see whether small modifications at the rear of the store could be devised to restore the tail effectiveness. Such a store should then behave reasonably correctly in a curved flow field under an aircraft.

ISOLATED STORE TESTS

TEST PROGRAMME

Tests were first made on a store in isolation in order to determine the effects of possible rear end distortions on the free-air performance of the store. Wind-tunnel testing has been confined to a typical bomb shape, since the fin-boat-tail configuration poses severe problems in fitting a support system of adequate strength and rigidity without introducing too much distortion. Models were made at 20% scale to enable minimal support systems to be tested. Figure 1 shows the basic store, designated by 0 followed by 14, indicating a fin span of 1.4 diameters. The first distortion has a cylindrical section over the fin base to accommodate the preferred diameter of sting for use at 8% scale. This model was also tested with fin spans of 1.2 and 1.3 diameters. The second variant is designed to take the smallest diameter fin deemed to be feasible. The last distortion retains a shortened tail-cone and extends the parallel body section to preserve the same tail arm. These models were tested over a range of Mach numbers up to 1.2, varying both incidence and roll angle but the comparisons made here are only for a Mach number of 0.9 and an incidence of 20 degrees. The differences noted are approximately proportional to incidence, while the effects of Mach number, although significant, do not affect the general conclusions.

EFFECT OF TAILSPAN

The effect of changing the tail span on the store with distortion 1 which is the preferred distortion from design consideration, is shown in figure 2. Here we have plotted the incremental differences from the values of loads on the undistorted store. It can be seen that there is a significant trend with roll angle for the normal force and pitching moment. If we are looking for an analogous store, then a fin span just above 1.3 diameters is required at zero roll while a span of almost 1.4 diameters is needed at 45 degrees roll. By choosing a span of about 1.35 diameters, however, we can halve the mismatch with the undistorted store. Taking account of the size of C_N and C_m at this incidence, this means about $\pm 5\%$ error in C_N and $\pm 10\%$ in C_m as roll angle changes.

Looking at the lateral forces however, we see that the rear-end distortion

produces quite large errors in C_Y and C_n which are not affected by changes in fin span. Decreasing the span also worsens the match in rolling moment. Hence no satisfactory analogous store appears to be possible by simple change of fin span.

EFFECT OF DISTORTIONS

If, next, we look at the changes arising from distortion 2, the reduced diameter collar, and distortion 3, the lengthened centre section and shortened tail cone, we see from figure 3 that no significant gains are to be had on longitudinal loads from distortion 2 compared with distortion 1, and although distortion 3 gives a better agreement in normal force, it still exhibits a strong trend with roll angle in the pitching moment error curve. As regards lateral forces and moments, distortion 2 offers a small improvement but shortening the tail-cone gives the best agreement. Hence, from a consideration of loads on the isolated store, it is concluded that distortion 3 provides the best simulation and distortion 2 has no great advantage over distortion 1 and leads to a weak and flexible sting. However, since distortion 3 involves modifying the central part of the body where store to store interference is high during carriage, it was decided to continue investigations with distortion 1.

SCALE EFFECTS

An assessment of the effects of scale was made by adjusting the pressure in the tunnel to give a reduction in Reynolds number from 20% to 8.3% scale. Transition was fixed by ballotini bands near the nose of the body and behind the fin leading edge. No detectable difference could be detected within the experimental scatter.

CARRIAGE LOADS

DISTORTION AND STING EFFECTS

In order to assess the effect of distortion and the presence of a sting on loads measured in carriage, five component measurements through a side support balance have been made on stores mounted on the inboard pylon inner shoulder position on a TER on Phantom. An undistorted 014 store and a distorted 114 store were tested with and without dummy stings supported from the parent aircraft sting. Figure 4 shows the difference in loads from the basic store. Except for the yawing moment, the errors due to the after-body distortion are small and the additional change due to adding the sting are even smaller and tend to reduce the total error. The error in the yawing moment, however, is considerable, amounting to some 50% of the true load at low aircraft incidences. Even so, the percentage errors for the comparable stores in free air are more than double this, thus indicating that correction factors derived from isolated stores should not be applied to carriage loads. These tests have been done on a single store on a TER. With additional stores present the effects can be greater.

MEASUREMENT ACCURACY

We had some doubts on the accuracy of carriage loads measured at this scale and

so, at the beginning of the programme, examined the effects of small variations in model detail. Initially, these tests were to examine whether the presence or absence of sway braces had a significant effect on store loads. Results are shown for the bottom store on a fully loaded TER on the centreline station. Looking first at the solid curves in figure 5, in which crosses indicate the absence of sway braces, it is seen, not only that significant differences were observed in the longitudinal loads, but also that large yawing forces and moments could arise even though these measurements are for a store on the aircraft centreline. These tests were done with a solid side support for the store and were then repeated with venting at the junction of the store and rack similar to that in full scale carriage. These results are represented by the chain dotted lines which show that some of the larger values of yawing force and moment are now avoided. Note that at the higher incidences of the parent aircraft, there is a tendency for differences between the various representations to become smaller. From other tests which have been made, it is thought that, when the channels between the stores and the rack are aligned to the flow, separations are induced over the tail region. At incidence however, the flow pattern changes with separations further forward leading to less sensitivity to the detailed geometrical shape of the passage ways. In figure 6 a comparison is made of the loads on the shoulder store on the inboard pylon as measured in the USA and in the UK. These are for the same store in the same carriage configuration on the UK version of Phantom and at approximately the same scale. Again we have significant differences at low incidences of the parent aircraft, even a difference in the sign of the side force, but better agreement at higher incidences, which suggests possible differences in the detail modelling.

It is concluded from this comparison, firstly that flight test measurements of the aerodynamic loads are required to confirm carriage loads obtained in the wind-tunnel, and secondly, that care is required in the use of loads obtained from side support systems to validate sting-supported systems.

TRAJECTORY COMPARISONS

The assessment of the errors due to store distortion is not complete until account has been taken of their effect on the release disturbance and the accuracy of the delivery of the stores to the target. For these predictions, a knowledge of the variation of the loads due to the aircraft flow field is required. To solve this problem without the use of a captive trajectory rig we have used an analysis of actual motion of stores released in flight and observed by aircraft cameras, together with simulations of the ejection phase to obtain the approximate variation of store loads. The technique is still being developed but in figure 7 the full line and the crosses show the current standard of fit. If now the simulations are repeated using the aerodynamic characteristics of the stores with distortions 1 and 3 we obtain the results shown by circles and squares. These results indicate that the effects of store distortion are of the same order as the repeatability of the release disturbance measured in flight.

The trajectories have been continued to ground, using true store aerodynamics, to find out whether the discrepancies in the incidence pitch rate and velocity vector of the store when it reaches the edge of the aircraft flow field has a

significant effect on the impact point. Figure 8 shows the error in range as a function of height fallen, assuming straight and level release. At 450 kn these are small compared with other possible errors such as ballistic dispersion, aiming errors and trajectory repeatability in the wind-tunnel. The assumptions on the flow field effects have been applied to releases at 600 kn and the results show more significant errors, particularly since they form biases in the delivery system. The magnitude of the errors will also increase for stores with lower density or less stability.

To examine the effects of the large errors in the lateral loads due to distortions, a release from a pylon shoulder station on a yawed aircraft has been considered. The simulation assumes an exponential decay of the carriage loads. It is seen from figure 9 that the initial yaw disturbance is poorly represented, but an analysis of the overall effect on trajectory shows range errors of only 23 ft and line errors of 11 ft.

CONCLUSIONS

1 Distortion effects on loads differ in free air and in carriage.

2 An analogous store is therefore desirable but is difficult to design.

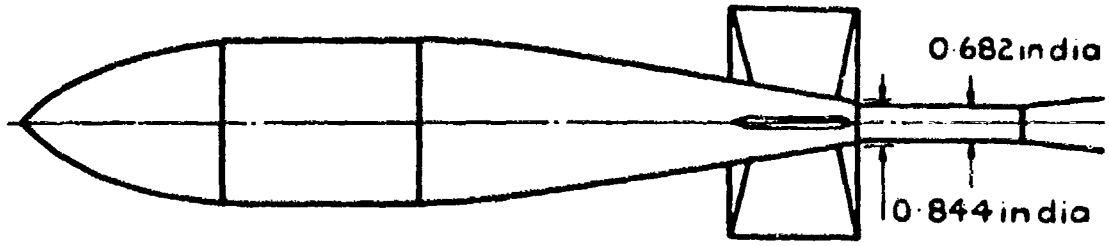
3 Sting effects on store loads in carriage are small for the cases considered.

4 Correct detail design of the model installation is essential for accurate carriage loads.

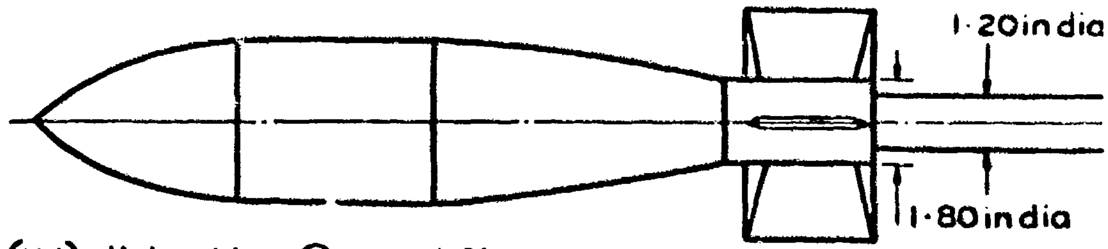
5 The effect of distortions on predicted release disturbances and trajectories is relatively small.

AUTOBIOGRAPHY

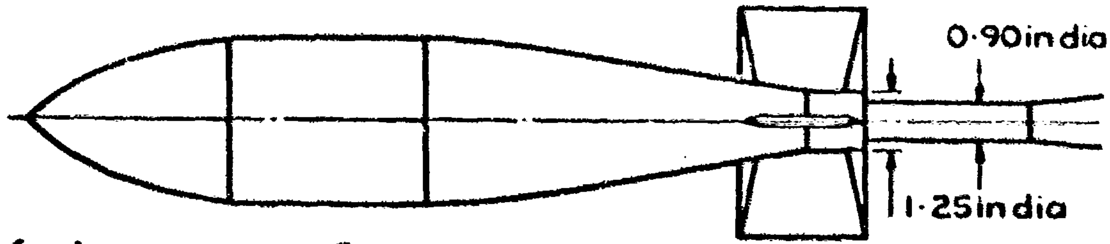
Mr Cane was awarded a BA Hons degree in Pure and Applied Mathematics at the University of Wales in 1942 and then worked for four years on Operational Research. Subsequently, he did research on shock waves and boundary layers at Imperial College London and the Cranfield Institute of Technology, receiving an MSc degree in 1949. Since then, he has worked mainly at the Royal Aircraft Establishment at Farnborough on the aerodynamics and performance of aircraft and weapons. He is currently Head of the Weapons Aerodynamics Section in Air Armament Department, and since 1970 has been engaged on a programme of store-separation research.



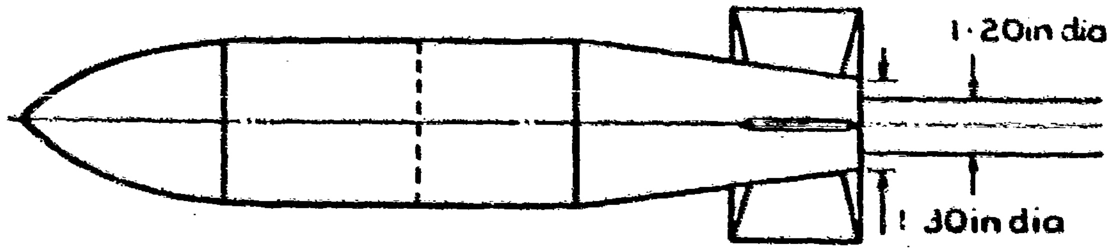
(014) undistorted store -1·4d fins



(114) distortion ① -1·4d fins
(112) 1·2d fins
(113) 1·3d fins



(214) distortion ② -1·4 d fins



(314) distortion ③ -1·4 d fins

FIG.1 STORE SHAPES TESTED

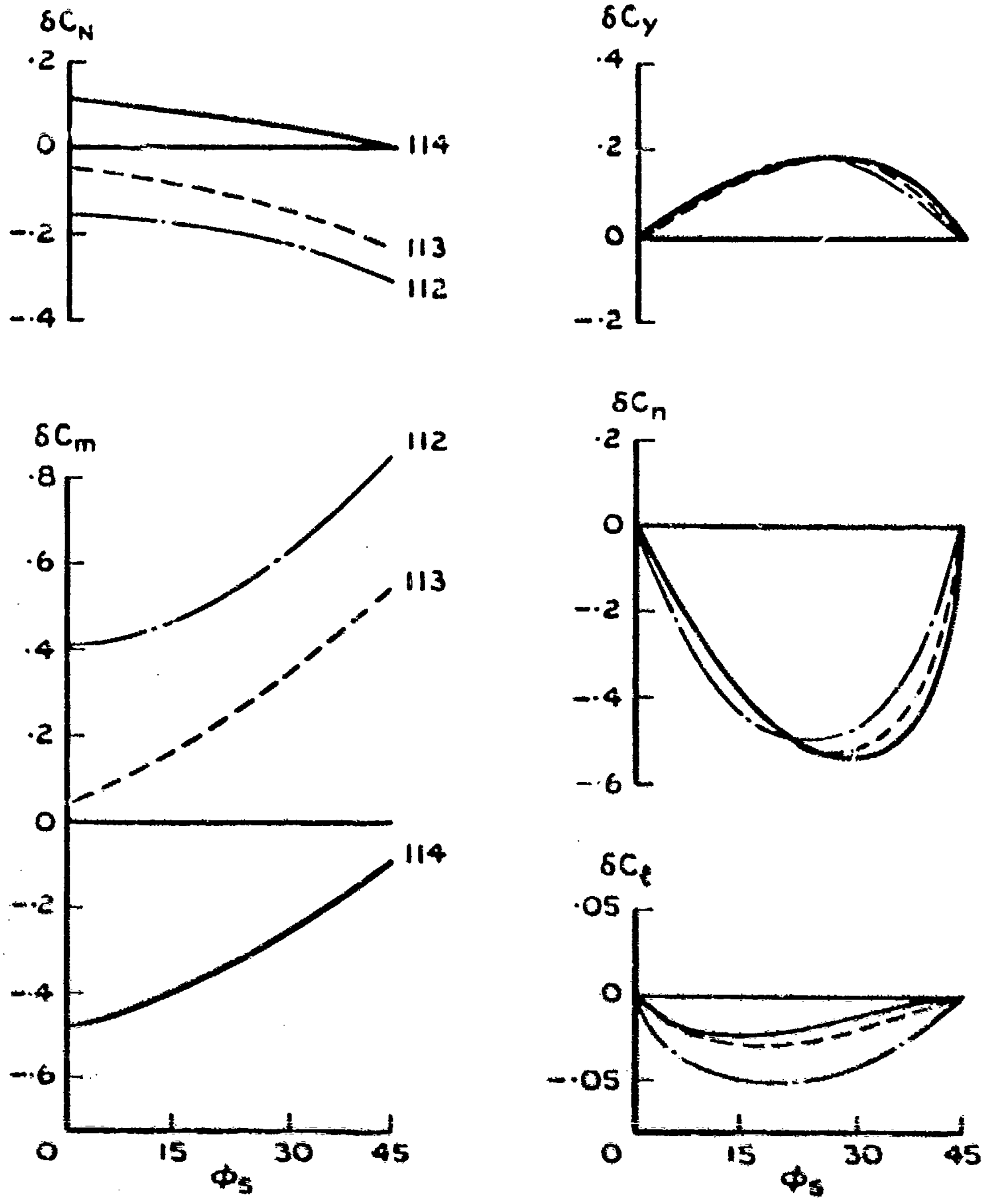


FIG. 2 CHANGES IN ISOLATED STORE LOADS DUE TO TAIL SPAN. MO·9; α_s 2O

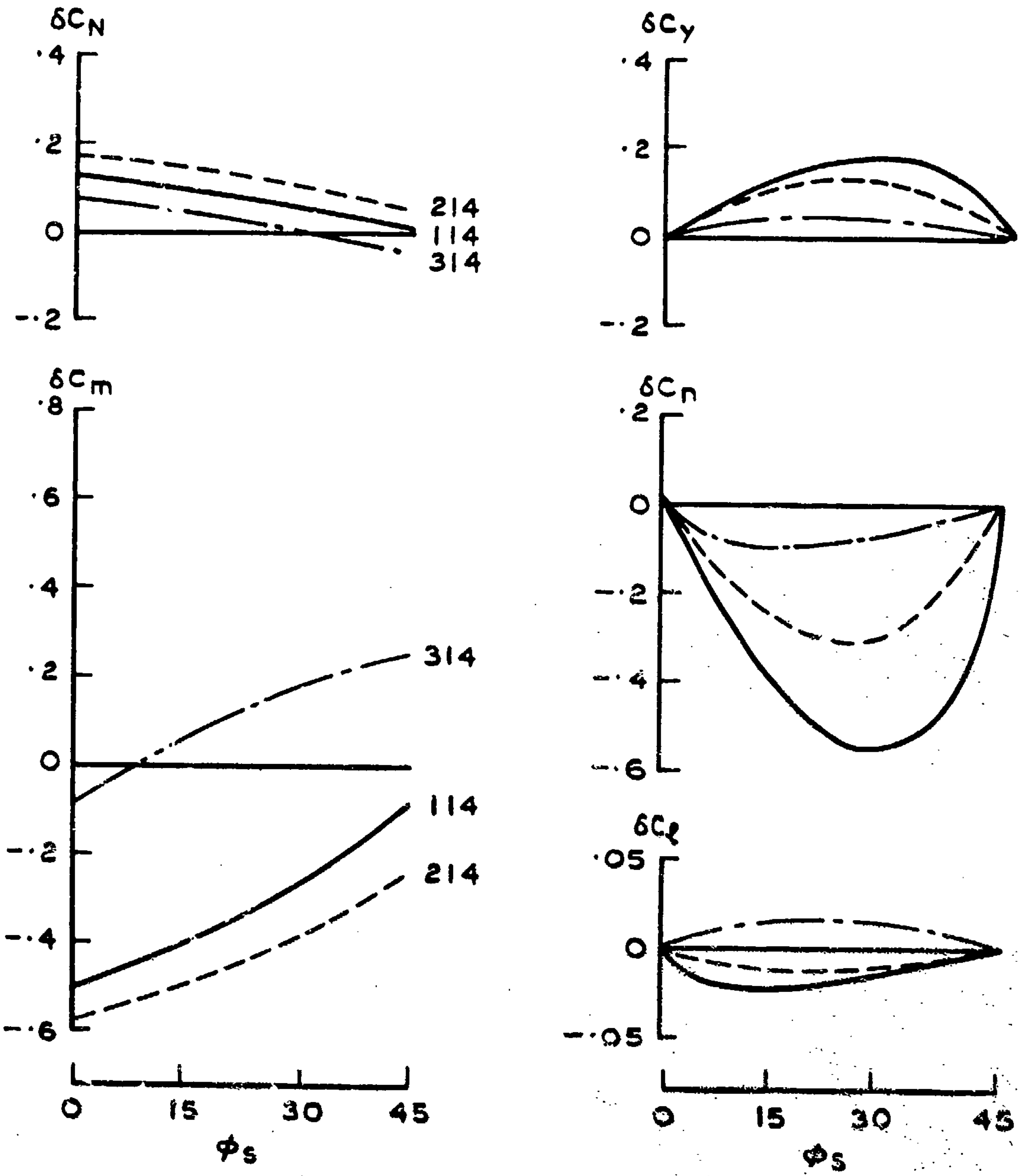


FIG.3 CHANGES IN ISOLATED STORE LOADS DUE TO DISTORTIONS MO·9 ; α_s 20

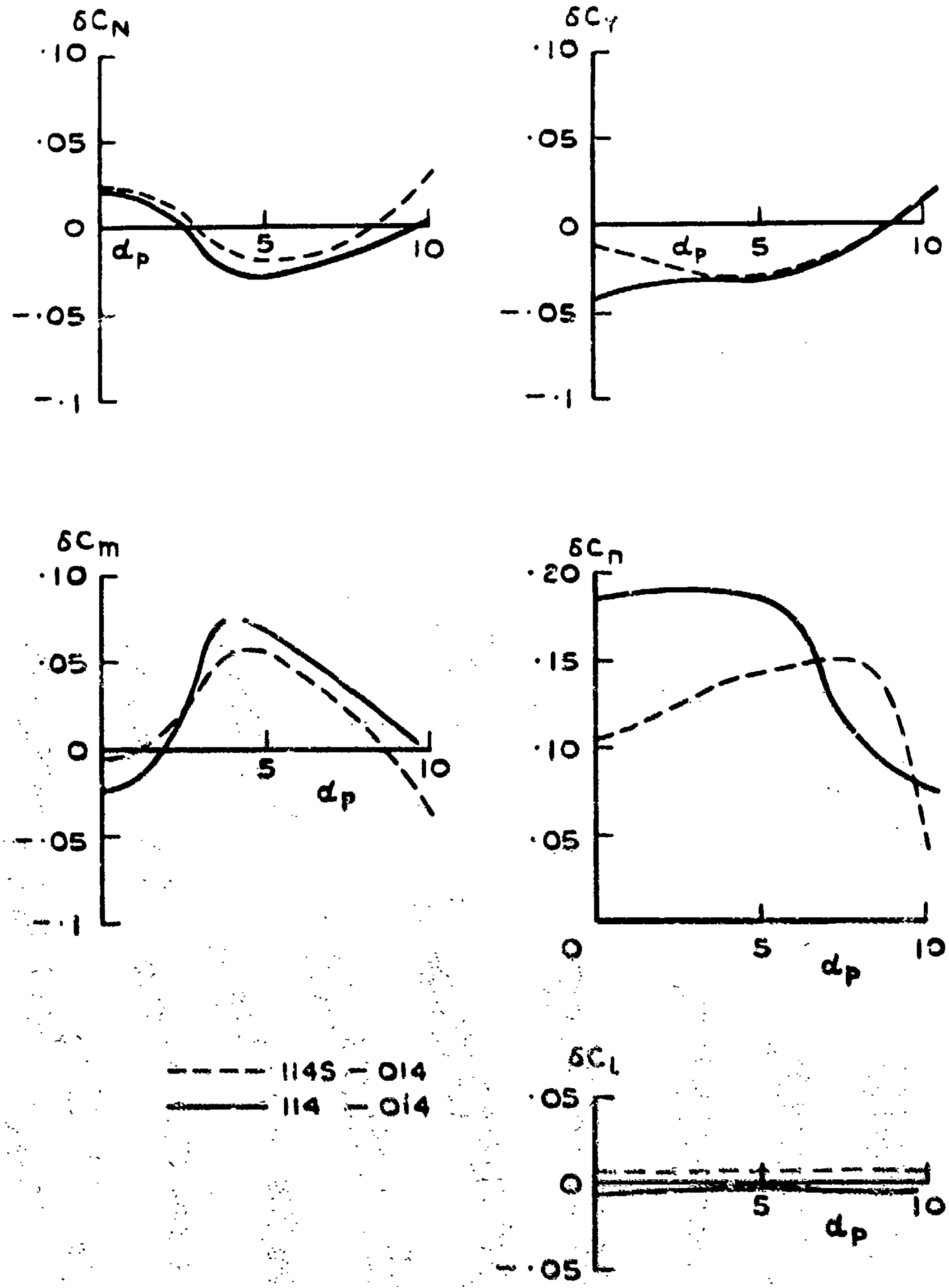


FIG.4 CHANGES IN CARRIAGE LOADS DUE TO DISTORTION WITH & WITHOUT STING MO·9

WE R 15745

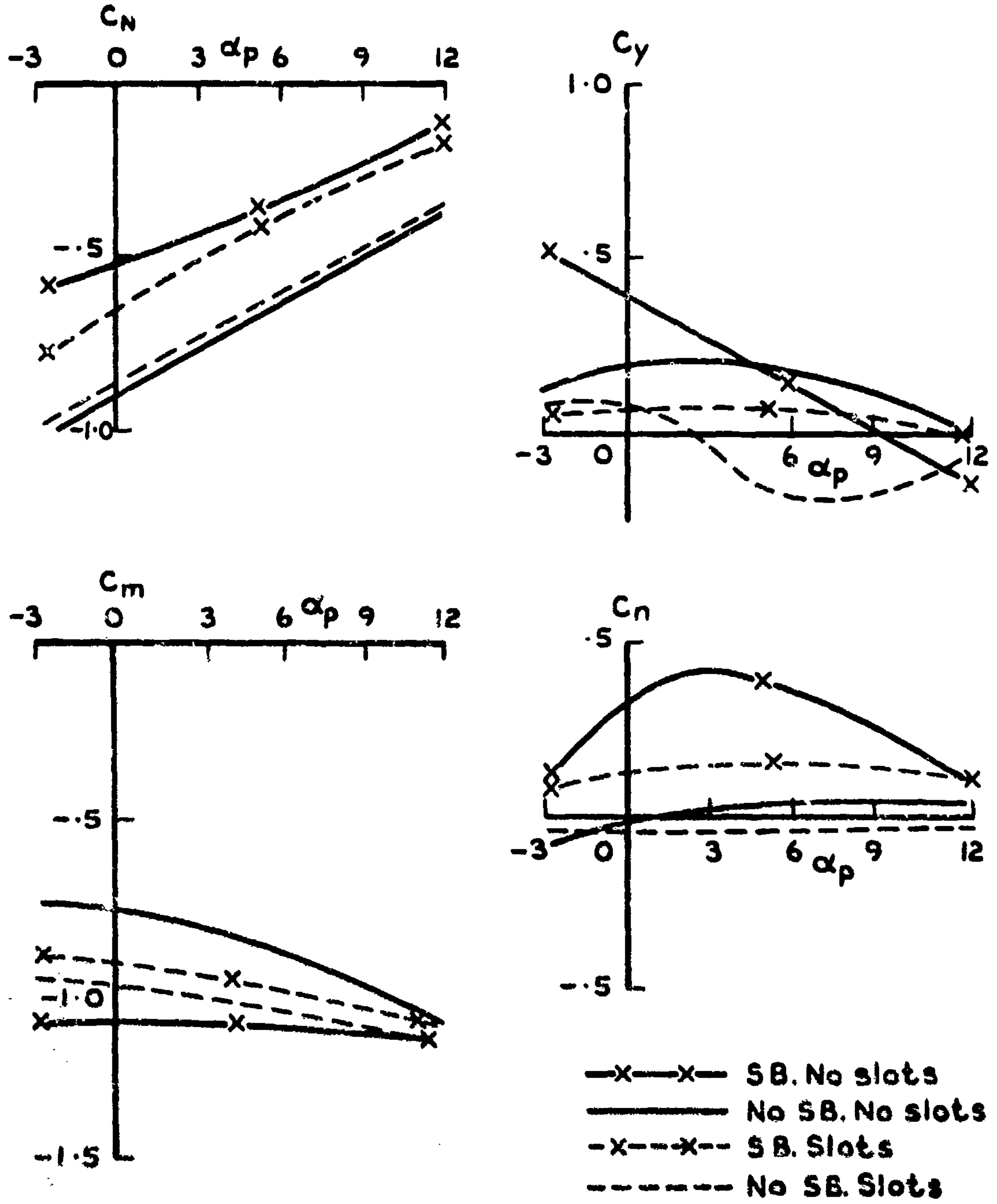


FIG. 5 EFFECT OF SWAY BRACES AND SLOTS
CENTRE LINE STORE MO·9

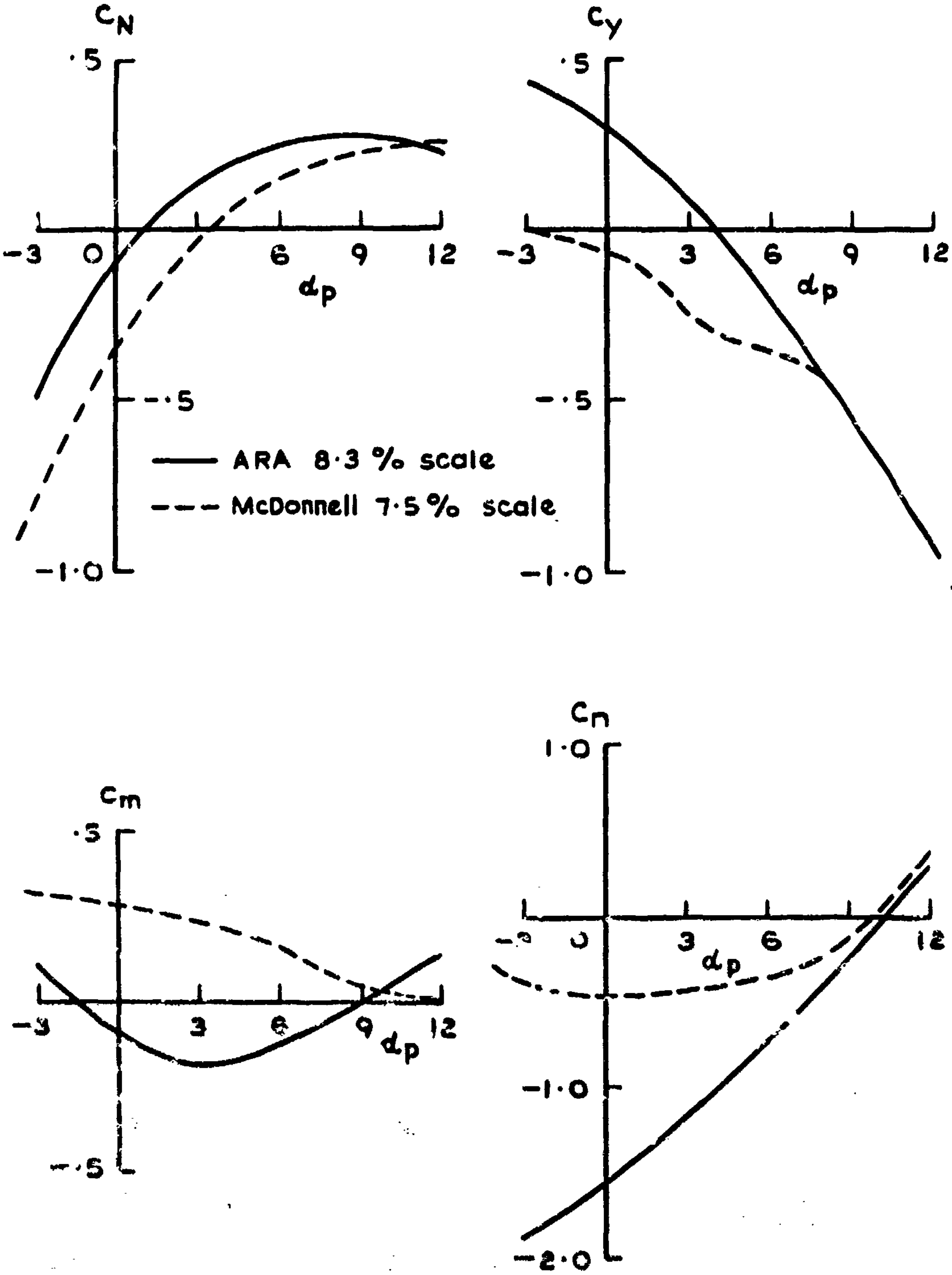


FIG.6 COMPARISON OF CARRIAGE LOADS MEASURED IN DIFFERENT TUNNELS MO·9

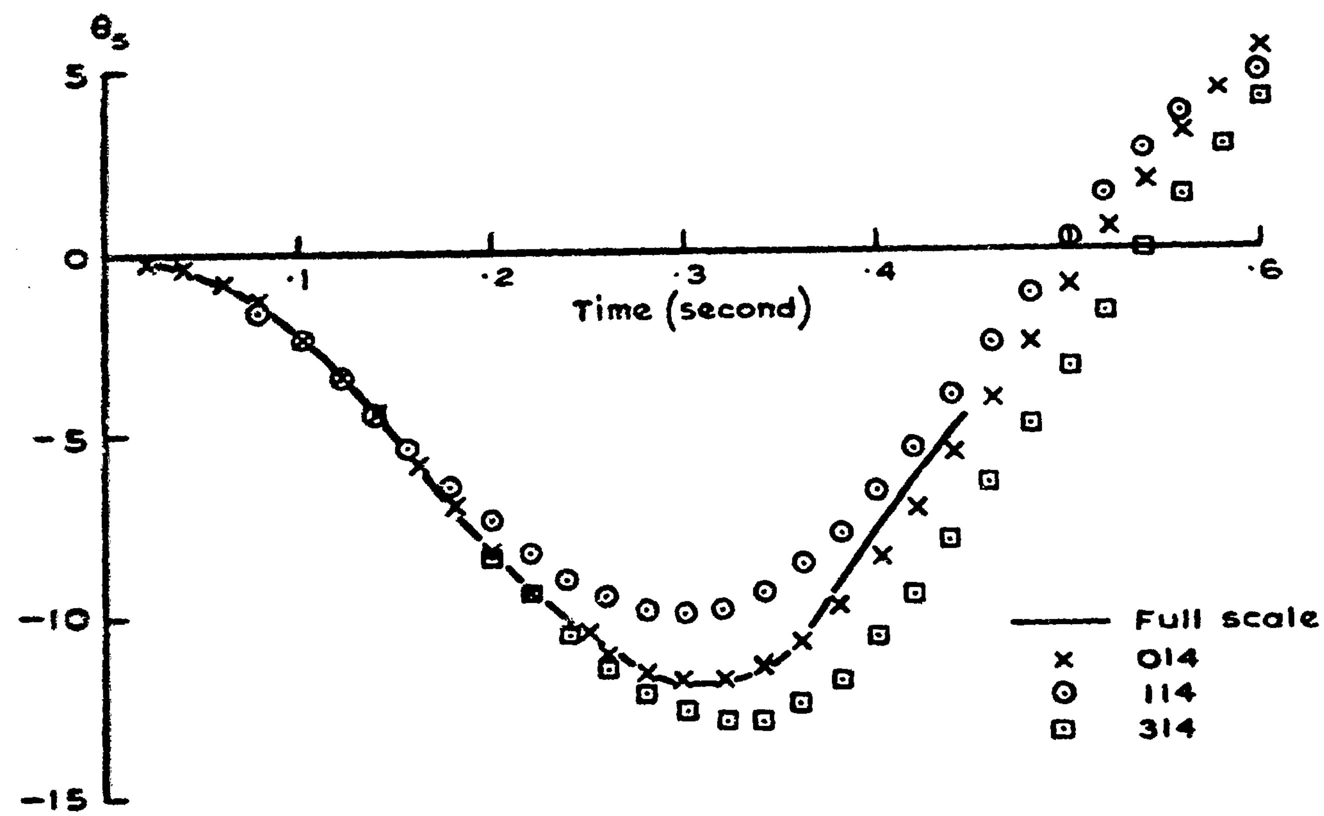


FIG. 7 COMPARISON OF PREDICTED AND FULL-SCALE RELEASE DISTURBANCE AT 450 kn (CENTRE LINE STORE)

UNCLASSIFIED

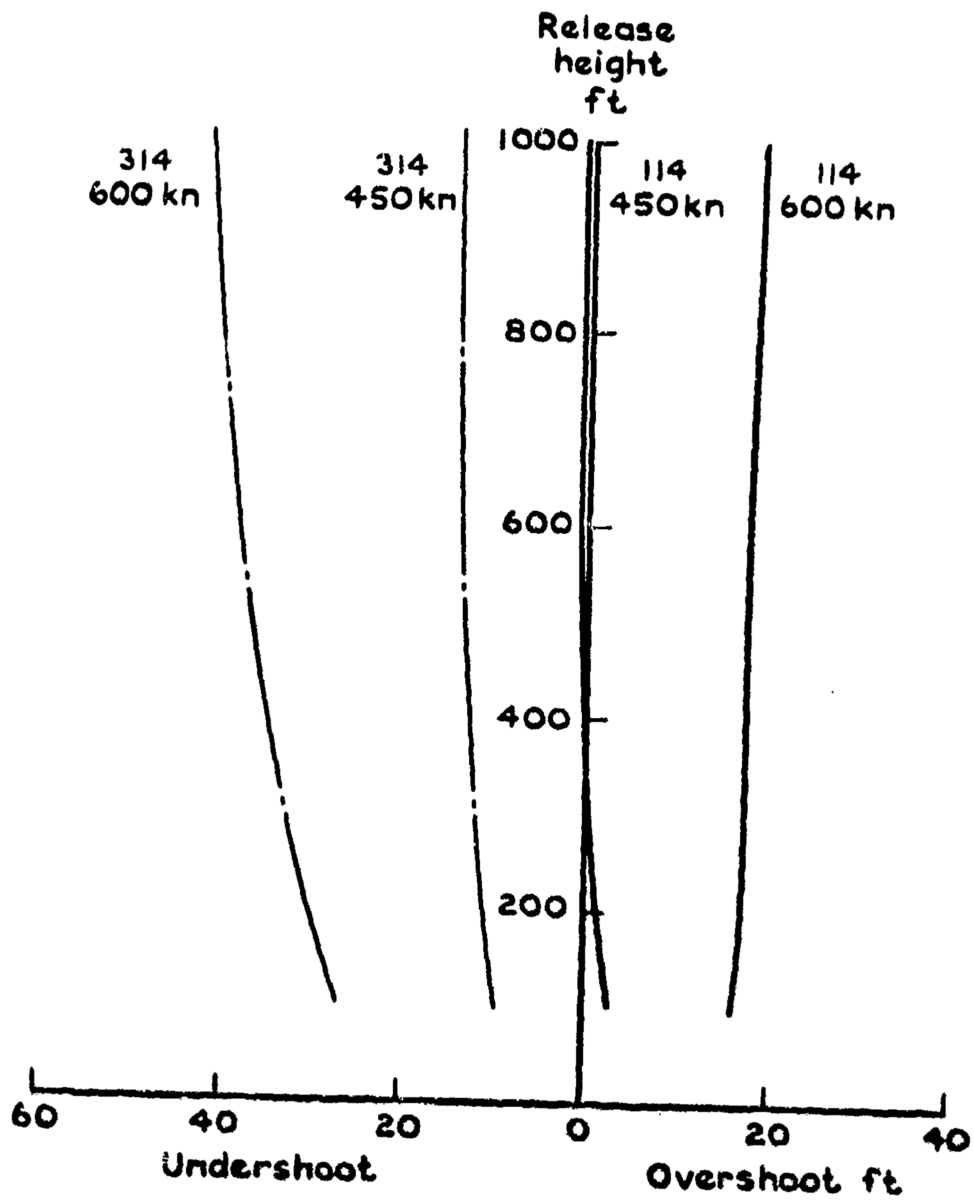


FIG. 8 EFFECT OF DISTORTION ON FORWARD THROW (CENTRE-LINE STORE)

W2 R 15749

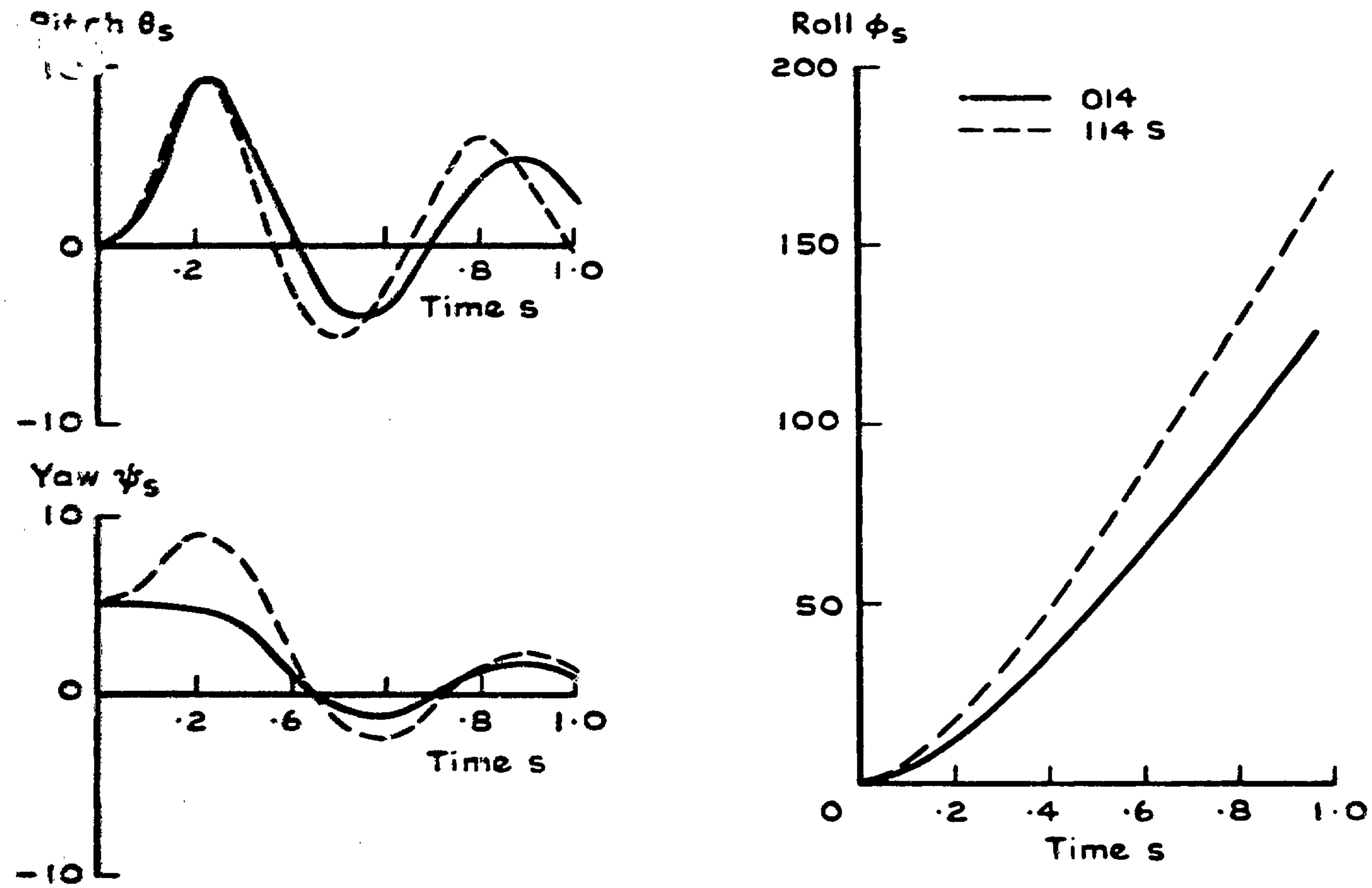


FIG.9 EFFECT OF DISTORTION ON RELEASE DISTURBANCE
MO·9; α_p O; β_p 5, (SHOULDER STORE)

PRELIMINARY DESIGN OF AN OPERATIONAL
F-4 CONFORMAL CARRIAGE
(U)
(Article UNCLASSIFIED)

by

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ABSTRACT. (U) Low Drag Carriage of external stores has been a design objective for all tactical fighters. Satisfaction of this objective is very difficult due to aircraft maintenance requirements, multiplicity of weapon suits, aircraft structural arrangement, and the internal packing density of the aircraft.

Preliminary design of a low drag conformal weapons carriage modification for the F-4 aircraft is described and application of the conformal carriage design methodology to the preliminary design of a high performance strike fighter is described.

Approved for public release, distribution unlimited.

INTRODUCTION

Development of conformal weapons carriage technology within The Boeing Company spans the period between 1960 and the present time. Most early work concentrated on wind tunnel investigations of aircraft configurations employing conventional pylon versus conformal weapons carriage suspension systems. The test data consistently indicated the superiority of conformal weapons carriage over pylon weapons carriage. In 1971, The Boeing Company designed, built, and installed a "boiler plate" model of a conformal carriage on an F-4B aircraft. The work was accomplished under contract N0060-71-C-1150 jointly funded by the Naval Air Systems Command and the Air Force Armament Test Laboratory.

Flight performance tests of the modified aircraft and weapon separation tests were performed at Naval Weapons Center, China Lake, California. The data obtained has been previously reported at the second Aircraft/Stores Compatibility Symposium in Sacramento during September 1973[1,10] in several confidential technical reports [2], [3], [4], [5], [6] and an unclassified design document.[7]

Contract funding and time schedules in this contract precluded development of a fully operational F-4 conformal carriage configuration; therefore, aircraft operational maintainability was not a preeminent design criteria. The flight test data obtained verified the wind tunnel test data previously collected. As a result of the aircraft performance The Boeing Company began preliminary design of operational conformal carriage configurations for the F-4 B/J and the F-4E. Funding was provided individually by U.S. Air Force Contract F08635-74-C-0080 from U.S. Air Force Armament Test Laboratory and by U.S. Navy contract N00123-74-C-2011 from Naval Air Systems Command through the Naval Weapons Center. The results of these two contracts and some Boeing Company funded investigations are discussed in detail within the body of the article. The complete technical reports for both contracts have been published as references 8 and 9.

The historical background of the program is illustrated in Figure 1.

CONFIGURATION COMPARISONS

The flight test aircraft shown in Figure 2 included a conformal carriage which covered the entire lower surface of the aircraft fuselage aft of the nose landing gear door. Figure 3 depicts the operational conformal carriage config-

uration for an F-4J. The operational carriage is approximately 50 inches wide as contrasted to the 96 inch width of the carriage flight tested. Also, the operational carriage extends from the forward edge of the nose landing gear door to the engine nozzle plane. This forward extension reduces the incidence angle of the carriage forward fairing from that for the flight test aircraft and minimizes the aerodynamic interaction effects between weapons in the forward row and the adjacent fairing surface. An operational F-4E conformal carriage configuration was tested in the NASA Ames 6 x 6 wind tunnel in April 1974. The data obtained was used to develop a performance envelope for the operational F-4E conformal carriage configuration. Figure 4 illustrates the performance improvement calculated for the F-4E conformal carriage and its comparison to the flight test data obtained with the F-4B conformal carriage.

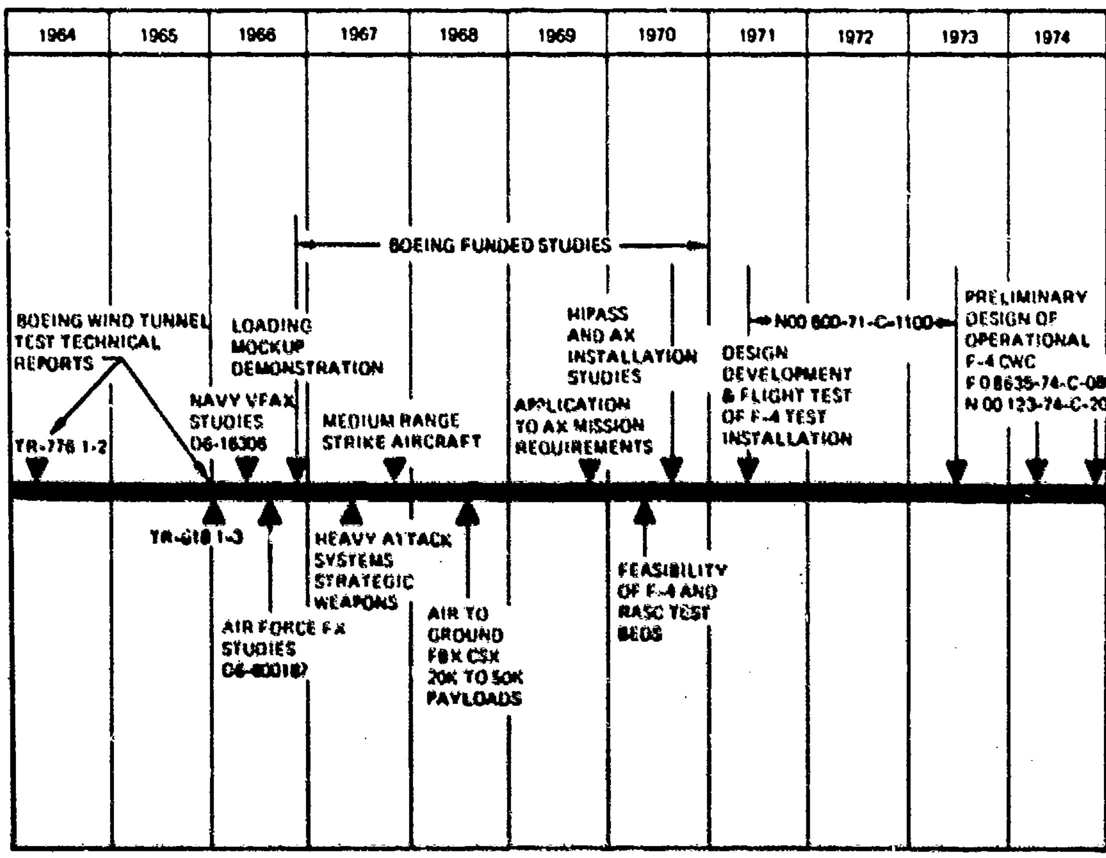


Figure 1. Conformal Carriage Development Program History

Figure 2. F-4B Conformal Carriage Flight Test Aircraft

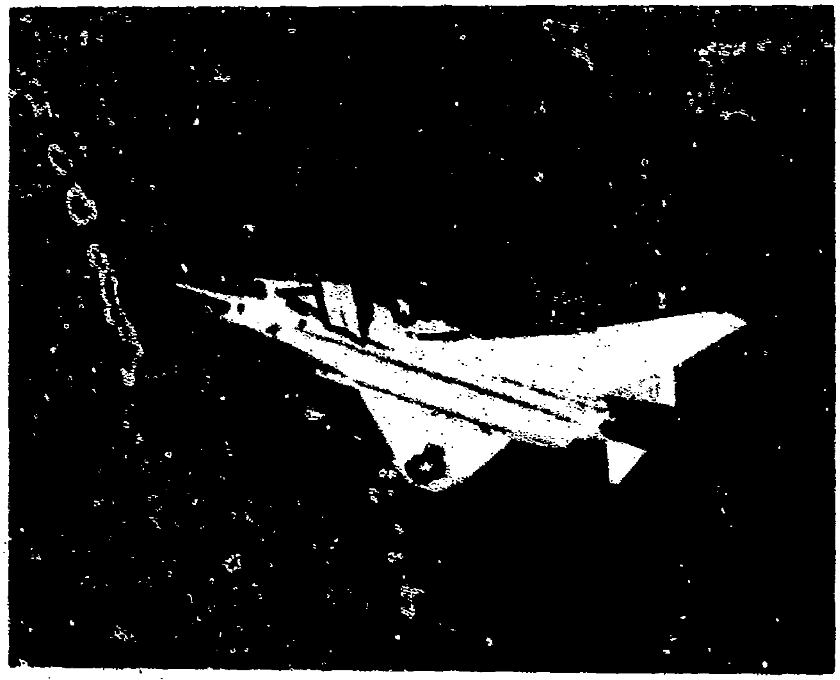


Figure 3. Operational F-4J

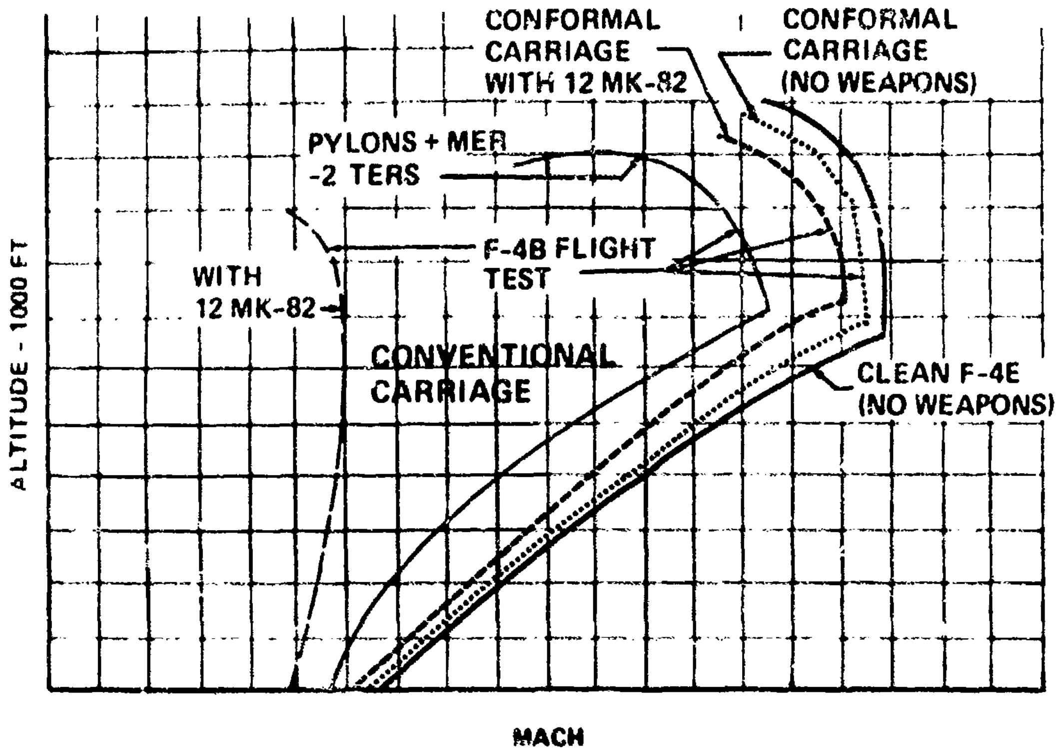


Figure 4. F-4B vs F-4E Conformal Carriage Speed Capability

AIRCRAFT LONGITUDINAL STABILITY

Aircraft longitudinal stability is an important consideration in selection of weapon loads and also weapon suspension locations. For the F-4 series aircraft, stability effects of external stores are most easily determined through the use of balance numbers and aft c.g. limit curves. The data shown in Table I lists the balance numbers for several weapons and suspension equipment as abstracted from NAVAIR 01-245FDB-1, F-4B Flight Manual.

Longitudinal stability of a conformal carriage F-4B is compared to an F-4B with conventional weapon suspension in Figure 5 and Table II.

Table I. Balance Numbers

WING MOUNTED WEAPONS WING STATION 1, 2, 8, OR 9		
WEAPON/TANK	Single mounted (one weapon at a station)	Cluster mounted (two or more weapons at a station)
	UNIT BALANCE NUMBER	
Wing tank and pylon (with weapons installed on stations 2 and 8)	29.8	—
Wing tank and pylon (without weapons installed on stations 2 and 8)	20.0	—
MK 81 (Snakeye! and ldgp)	1.8	2.4
MK 82 (Snakeye! and ldgp)	2.8	3.7
MK 83 Ldgp bomb	4.6	6.1
MK 86 Practice bomb	1.8	2.4
MK 87 Practice bomb	2.8	3.7
MK 88 Practice bomb	4.6	6.1
MK 77 Mod 1 fire bomb	14.3	19.1
MK 79 Mod 1 fire bomb	9.5	—
AN-M57A1 Banded lug GP bomb	2.8	3.7
AN-M81 Banded lug fragmentation bomb	1.1	1.5
AN-M88 Banded lug fragmentation bomb	1.1	1.5
LAU-3A/A or aero 7D rocket launcher	10.1	13.5
LAU-10/A rocket launcher	8.0	10.6
LAU-32/A/A or aero, 6A-2 rocket launcher	3.9	5.2
CBU-1A/A, CBU-2A, or CBU-2A/A	10.0	13.3

WING MOUNTED SUSPENSION EQUIPMENT	
WING STATION 2 OR 8	UNIT BALANCE NUMBER
LAU-17/A wing missile pylon	6.9
LAU-17/A wing missile pylon + LAU-7/A guided missile launcher	9.1
LAU-17/A wing missile pylon + TER adapter + TER rack	13.5
WING STATION 1 OR 9	
Wing tank pylon	4.3
Wing tank pylon + MER adapter + MER rack	11.4

Note 1. Tandem weapons count as a single weapon.

Table II
F-4B Longitudinal Stability Calculations

Configuration	Stability Index Number	Gross Weight Lbs.	C.G. Location % MAC.
Conventional Aircraft			
OEW	0	29000	32.20
Full Internal Fuel	0	42505	33.70
+ ℄ Fuel Tank	0	46834	34.03
+ Station 2 & 8 TER's	27.0	47372	33.77
+ Station 1 & 9	49.8	48054	34.13
+ 12 MK82 Bombs	94.2	54354	32.39
Conformal Carriage Aircraft			
OEW	0	29900	32.00
Full Internal Fuel	0	43405	33.14
+ 2 370 gal. Wing Tanks	40.0	49117	33.77
+ 12 MK82 Bombs	40.0	55417	33.22

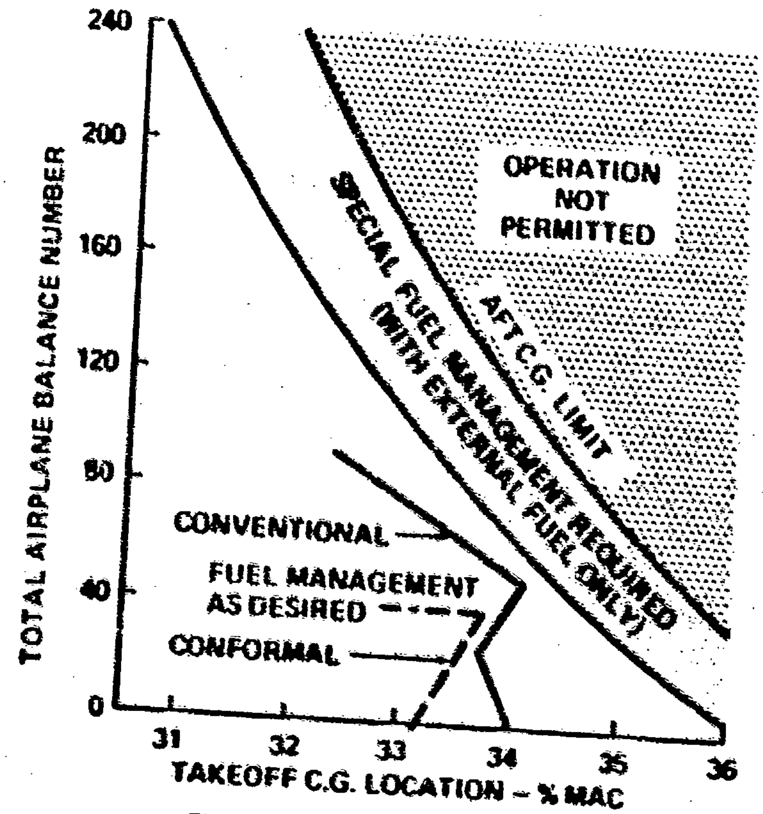


Figure 5. F-4B Aft C.G. Limits

Installation of leading edge slats on the F-4E changes the longitudinal stability of the aircraft as shown by the maximum allowable aft c.g. limits given in Figures 6 and 7. The maximum allowable aft c.g. position is shifted forward approximately 1% M.A.C. by the addition of the leading edge slats. Carriage of external stores on conventional pylons further reduces the aircraft longitudinal stability by the effect of increasing the balance (or stability index) number faster than the forward shift in c.g. location due to weapon weight added forward of balance point.

Table III contains stability calculations for F-4E aircraft with conventional and conformal weapons carriage systems.

Table III
F-4E Longitudinal Stability Calculations

CONFIGURATION	SIN	GROSS WEIGHT	% MAC
CONVENTIONAL F-4		LBS.	
OEW	0	31,930	26.1
FULL INT. FUEL	0	44,041	32.7
2 FULL 370 GAL. TANKS	40	49,467	33.2
PYLONS & TERs ON 2 & 8	103.6	50,005	32.94
PYLON & MER ON 5	103.6	50,275	33.00
6 MK82 ON 2 & 8	125.8	53,425	30.83
6 MK82 ON 5	125.8	56,575	30.35
CWC F-4			
OEW	0	32,830	25.9
FULL INT. FUEL	0	44,941	32.44
2 FULL 370 GAL. WING TANKS	40	50,653	33.13
+ 12 MK82 BOMBS	40	56,953	32.67

F-4E aircraft with conventional armament suspension equipment require very careful handling when fully loaded with internal fuel and two 370 gallon external wing tanks. Addition of the weapons on stations 2, 8, and 5 increases gross weight and adds to the stability index number but moves the c.g. location forward out of the caution zone, as shown in Figure 6.

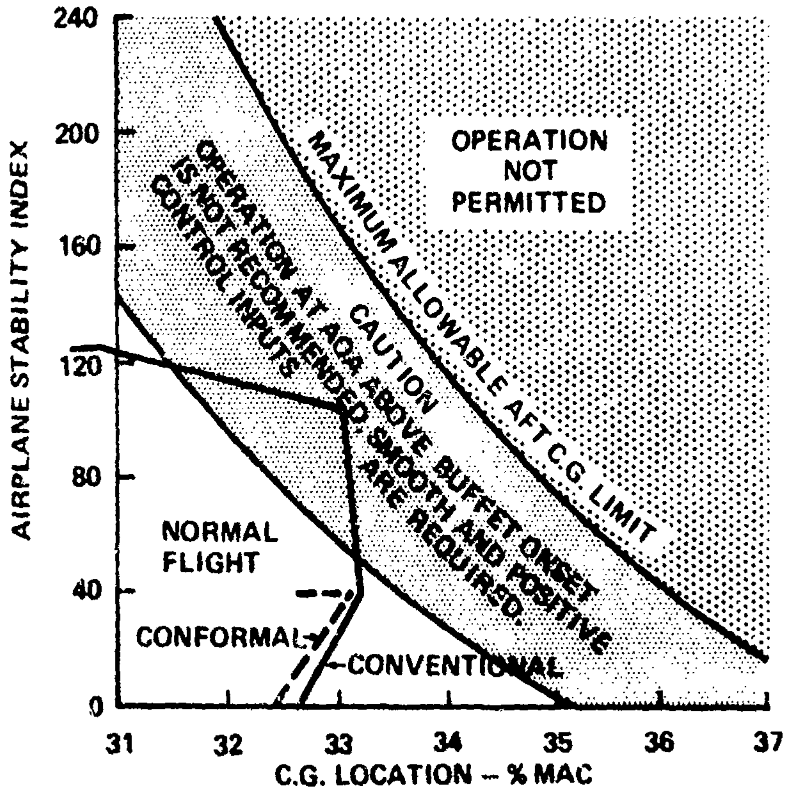


Figure 6. F-4 C,D, & E Aft C.G. Limits (Before T.O. 1F-4E-566 L.E. Slats)

Incorporation of the leading edge slats brings the maximum allowable aft c.g. limit much closer to the c.g. location for the aircraft with full internal and two 370 gallon external wing tanks. Addition of weapons on stations 2, 8, and 5 again moves the c.g. forward out of the caution zone even though there is an increase in the stability index number. In the event an aircraft in this condition encounters a high gust condition while flying at high angles of attack, perhaps during a refueling operation, the aircraft may become unstable and begin a violent pitch up maneuver. The pilots first impulse is to lighten ship and jettison the bombs which he has been told destabilize his aircraft. If the bombs are jettisoned the c.g. immediately moves further aft and the aircraft becomes even more unstable although the stability index number has been reduced. At this point the crew is apt to "punch out" and the aircraft is lost.

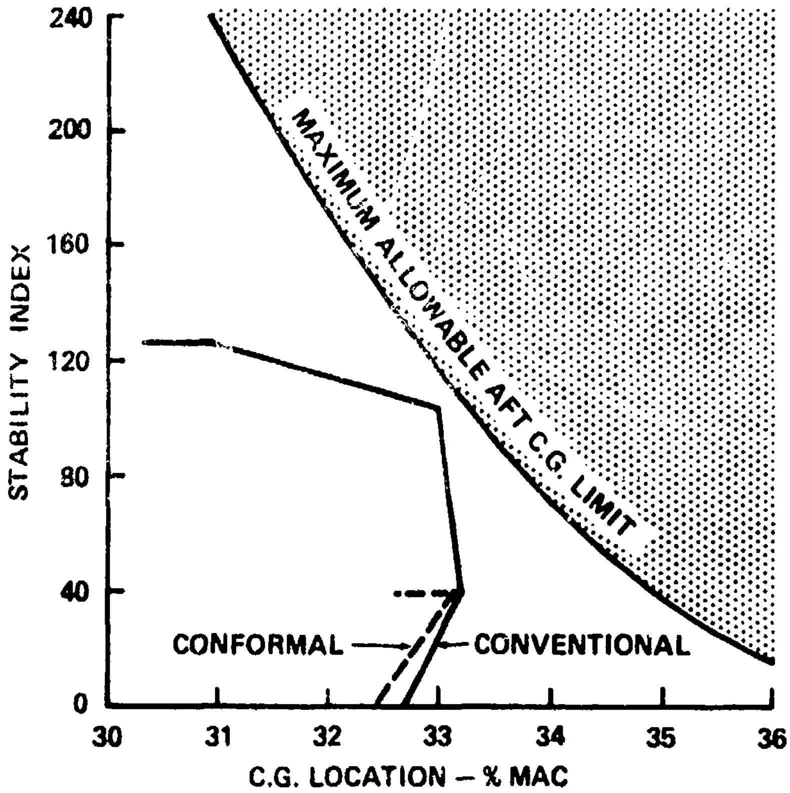


Figure 7. F-4E Aft C.G. Limits (After T.O. 1F-4E-566 L.E. Slats)

Note that the conformal carriage F-4E aircraft c.g. location never is within the caution zone and has a very much enhanced stability margin. Qualitative evidence of this enhanced stability margin are the reports of the test pilots who flew the F-4B flight test aircraft. Their comments were: "The conformal carriage aircraft with installed weapons flew and handled like a clean but heavy F-4." Figure 8 depicts the pitching moment coefficient for three F-4 configurations.

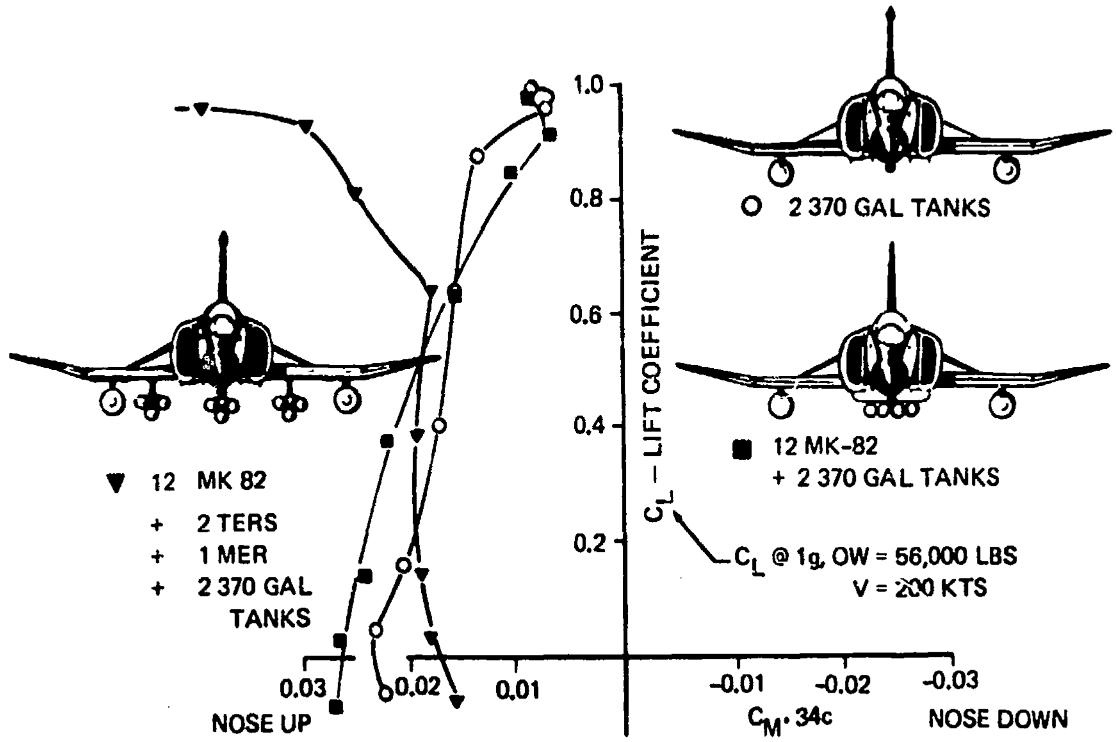


Figure 8. Pitching Moment Coefficient

The performance gains previously described are not obtained without penalty. Installation of the operational conformal carriage increases the clean aircraft OEW by 900 lbs. because the weapon suspension system cannot be removed as in the case of conventional pylons where 960 lbs. of pylons, adapters, and 4 TER's can be removed to clean up the aircraft.

The weapon ejectors used on pylon mounted systems cannot be used in operational conformal carriage installations because the ejector access is severely restricted in the conformal carriage installation. Furthermore safety considerations presently require the ability to jettison an ejector and its associated support structure if the ejector malfunctions. Obviously such a method of jettisonning a "hung" bomb is quite difficult in a conformal carriage installation. Another perhaps better approach may be to provide weapon jettison capability within the ejector itself so that the malfunctioning ejector can be returned for examination and analysis.

A third and most critical consideration is that of aircraft maintainability with an installed conformal carriage.

MAINTAINABILITY CONSIDERATIONS

The F-4 aircraft is arranged for servicing through the bottom of the fuselage. Such an arrangement is convenient for the basic aircraft, but when the conformal carriage is installed access to these service points becomes quite difficult. Consequently some servicing points must be relocated and others paralleled with new fittings in locations more accessible when the conformal carriage is installed. The critical items are:

1. Pneumatic System

The system pressure gage, air charge valve, and canopy emergency air pressure gages must be relocated to permit access at any time.

2. Utility Hydraulic System

The service fittings must be retained in their existing locations but parallel fittings are required in some more accessible location. The system accumulator reservoir fluid level indicator cannot be inspected when weapons are installed on the conformal carriage therefore a parallel fluid level indicator is required in another location.

3. LOX System

The F-4 LOX converter is too bulky to be relocated so the conformal carriage must be designed to permit access to this converter during a turn around operation.

4. Auxiliary Air Doors

The existing doors hinge downward approximately 45° about hinges located on the aircraft keel beam. The door motion and location is such that interference exists between the door and the conformal carriage structure. As a consequence the door function will be duplicated by a rolling type door which fits within the carriage structure. In the flight test program dual louvered doors were employed. During installation, an interference between door control links, engine oil lines and throttle quadrants was found, requiring deletion of the aft control links on the louvered doors. Elastic deformation of the louvers due to pressure loading during some flight conditions permitted the door open warning light to come on which was disconcerting to the pilots. The new system incorporates both positive seals and overpressure relief provisions.

5. F-4E Cartridge and Pneumatic Starter Access

Revisions to the ducts, cartridge breech, and exhaust deflector have been devised to permit access with weapons installed on the conformal carriage.

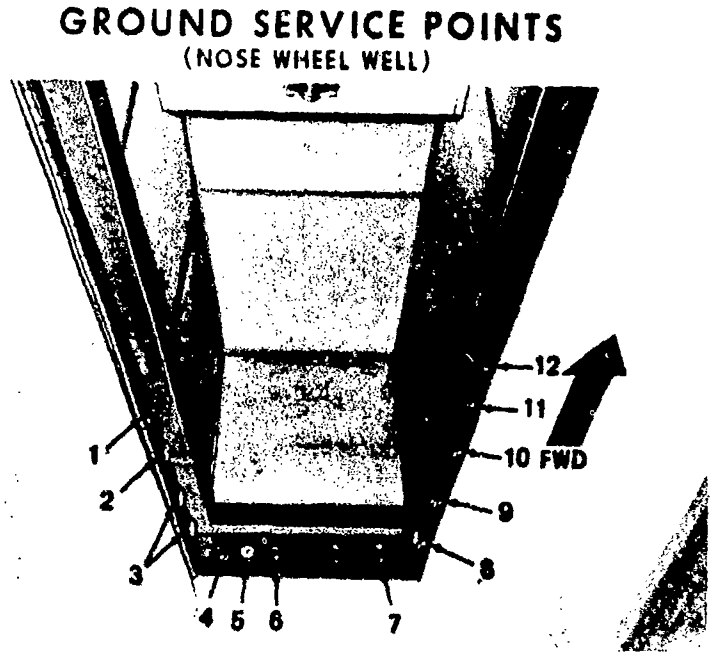
6. F-4 B/J Pneumatic Starter Access

The pneumatic starter duct fitting on the left side of the aircraft is located directly above a potential weapon tail fin assembly. Therefore the duct fitting must be moved outboard on the bottom of the conformal carriage to permit engine start. A similar situation existed on the flight test vehicle so the access point was moved to the side of the conformal carriage. No problems were encountered with this location unless the normal Navy F-4 cockpit checklist was followed. Normally, both engines are started and the aircraft flight control systems cycled while the starter hose is attached to the aircraft. Operation of the wing flaps with the hose in place damaged the duct access door and the inboard corner of the left wing flap. Several instances of this type of damage occurred during the flight test program.

7. Ground Refueling Point

An interesting problem developed in the flight test program which has been resolved in the operational design. The ground pressure refueling point is located behind an access door in the boundary layer bleed duct area on the aircraft right side. The shutoff valve is opened by an extension from the fueling nozzle which is operated by a lever on the nozzle assembly. On the F-4 series aircraft the nozzle can be inserted in three possible orientations in the fitting with adequate clearance to rotate the locking collar 15° to the locked position and subsequently operate the valve handle. The close proximity of the conformal carriage permitted nozzle insertion in only one of the three possible orientations with locking collar rotation and subsequent valve handle operation. It is not practical to modify the nozzle to fit the F-4 conformal carriage aircraft since the nozzle will then probably not satisfy fueling requirements for other aircraft. Therefore the nozzle receptacle on the F-4 must be reoriented to simplify fueling with the standard nozzles.

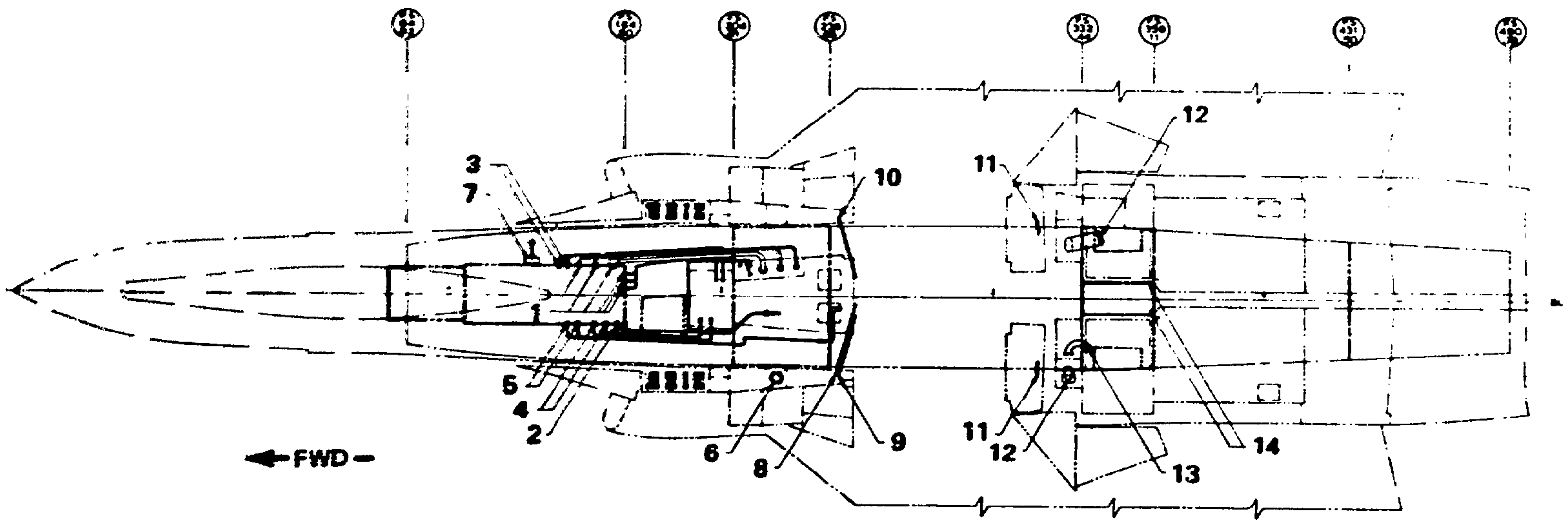
Figure 9 depicts the ground servicing points relocated to the nose wheel well.



1. AIR CHARGE VALVE
2. PNEUMATIC SYSTEM PRESSURE GAGE
3. CANOPY PRESSURE GAGES
4. RSVR AIR BLEED VALVE
5. ACCUMULATOR GAGE
6. ACCUMULATOR CHARGE VALVE
7. UTILITY HYD. RSVR LEVEL GAGE
8. UTILITY HYD. SUCTION RTN.
9. UTILITY HYD. RSVR. FILL
10. UTILITY SYSTEM PRESSURE
11. STATIC DRAIN
12. PITOT DRUM

Figure 9. Nose Gear Well Service Points

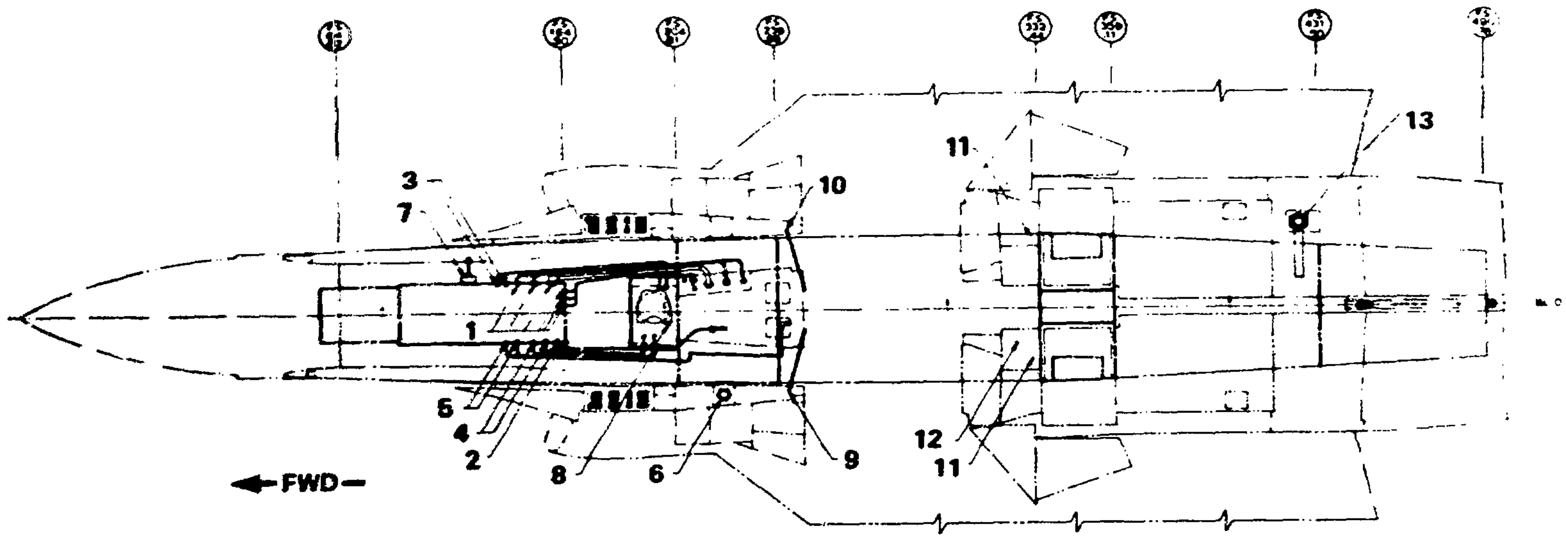
Figure 10 illustrates the modifications required in the F-4E servicing points and compartment drains, while Figure 11 depicts the changes required in an F-4 B/J.



BOTTOM VIEW

1 UTILITY HYDRAULIC SYSTEM SERVICE FITTINGS
   a. SUCTION RETURN
   b. RESERVOIR FILL
   c. UTILITY PRESSURE
   d. RESERVOIR AIR BLEED VALVE
   e. ACCUMULATOR PRESSURE GAGE
   f. ACCUMULATOR AIR CHARGE VALVE
2 UTILITY HYDRAULIC SYSTEM RESERVOIR FLUID LEVEL INDICATOR
3 PITOT AND STATIC DRAINS
4 FWD AND AFT CANOPY EMERGENCY AIR BOTTLE PRESSURE GAGES
5 AIR CHARGE VALVE AND PNEUMATIC SYSTEM MANIFOLD PRESSURE GAGE
6 REFUELING SYSTEM FITTING, ROTATE 60°
7 BOMB RELEASE INTERVALOMETER
8 AIR REFUEL RECEPTACLE DRAIN
9 NUMBER 1 COMPARTMENT DRAIN (AFT)
10 NUMBER 2 COMPARTMENT DRAIN
11 GENERATOR CONSTANT SPEED DRIVE AND NOSE DOME DRAIN
12 CARTRIDGE STARTER EXHAUST DUCT
13 PNEUMATIC STARTER INLET DUCT
14 MAIN FUEL CONTROL FUEL DRAINS

Figure 10. F–4E Service Point Modification



BOTTOM VIEW

1 UTILITY HYDRAULIC SYSTEM SERVICE FITTINGS
   a. SUCTION RETURN
   b. RESERVOIR FILL
   c. UTILITY PRESSURE
   d. RESERVOIR AIR BLEED VALVE
   e. ACCUMULATOR PRESSURE GAGE
   f. ACCUMULATOR AIR CHARGE VALVE
2 UTILITY HYDRAULIC SYSTEM RESERVOIR FLUID LEVEL INDICATOR
3 PITOT AND STATIC DRAINS
4 FWD AND AFT CANOPY EMERGENCY AIR BOTTLE PRESSURE GAGES
5 AIR CHARGE VALVE AND PNEUMATIC SYSTEM MANIFOLD PRESSURE GAGE
6 REFUELING SYSTEM FITTING, ROTATE 60°
7 BOMB RELEASE INTERVALOMETER
8 AIR REFUEL RECEPTACLE DRAIN
9 NUMBER 1 COMPARTMENT DRAIN (AFT)
10 NUMBER 2 COMPARTMENT DRAIN
11 GENERATOR DRAIN
12 CONSTANT SPEED DRIVE AND HYDRAULIC PUMP SEAL DRAIN
13 ENGINE STARTING AIR RECEPTACLE (RELOCATE OUTBD)

Figure 11. F-4B Service Point Modification

STRUCTURAL ARRANGEMENT

The operational F-4E conformal carriage design was developed for a specified weapon suit provided by AFATL while the F-4 B/J weapon suit was specified by NWC. Table IV lists the weapon suit specified for the F-4 B/J conformal carriage. Installation of one or two GAU-9A guns internally in the conformal carriage was studied as one of the weapon loads. The added depth required by an internal gun installation produced interference between catapult bridle and the outer weapons in the forward weapon row. The results of the trade study between internal GAU-9A gun and external GAU-9 gun pod is illustrated in Table V. The recommended gun installation is an external pod mounted on the conformal carriage centerline.

TABLE IV F-4B/J Conformal Carriage External Stores

Two GAU-9A guns plus ammunition storage located internally in conformal carriage.

STORE	QUANTITY INSTALLED		
	NWC		FEASIBLE
	DESIRED	REQUIRED	
MK20 MOD 0	12	6	11
APAM	12	6	11
MK-82-GP/SE	12	6	12
MK-83-GP/SE	6	3	5
MK-84-GP/SE	-	-	3
CBU-72(HSFAE)	4	2	3
MK-77	12	6	6
MK-82LGB	4	1	5
MK-83LGB	2	1	3
MK-84LGB	1	1	1
CTU-1	2	1	1
HARM	4	2	3
LAU-69	4	2	3
LAU-10	4	2	3
SUU-40	4	2	4
SUU-44	4	2	4
CBU-58	-	-	8
CBU-38	-	-	11
ASP	-	-	6
SUU-25C/A	-	-	4
SUU-51	-	-	6
B-57	-	-	3
MK-84 EOGB	-	-	1
AGM-65	-	-	4
B-43, B-61	-	-	1

TABLE V. F-4B/J Conformal Carriage External Stores Trade Study

Internal GAU-9A gun installation vs. External store quantities

STORE	QUANTITY INSTALLED	
	With Internal GAU-9A (From Table I)	Without Internal GAU-9A
MK-84LGB	1	3
MK-84EOGB	1	2
MK-77	6	8
SUU-51	6	8
MK-82LGB	5	6
ASP	6	8
CBU-72(HSFAE)	3	5
GAU-9 POD	-	1

NOTE: Stores shown are those affected by the internal GAU-9A installation. All other stores and quantities in Table I can be carried with or without internal GAU-9A installation.

For missions not requiring the gun additional bombs can be carried.

Typical of the weapon arrangements developed is Figure 12 where 6 Rockeye II bombs and the GAU-9 gun pod are integrated into a low drag weapon installation.

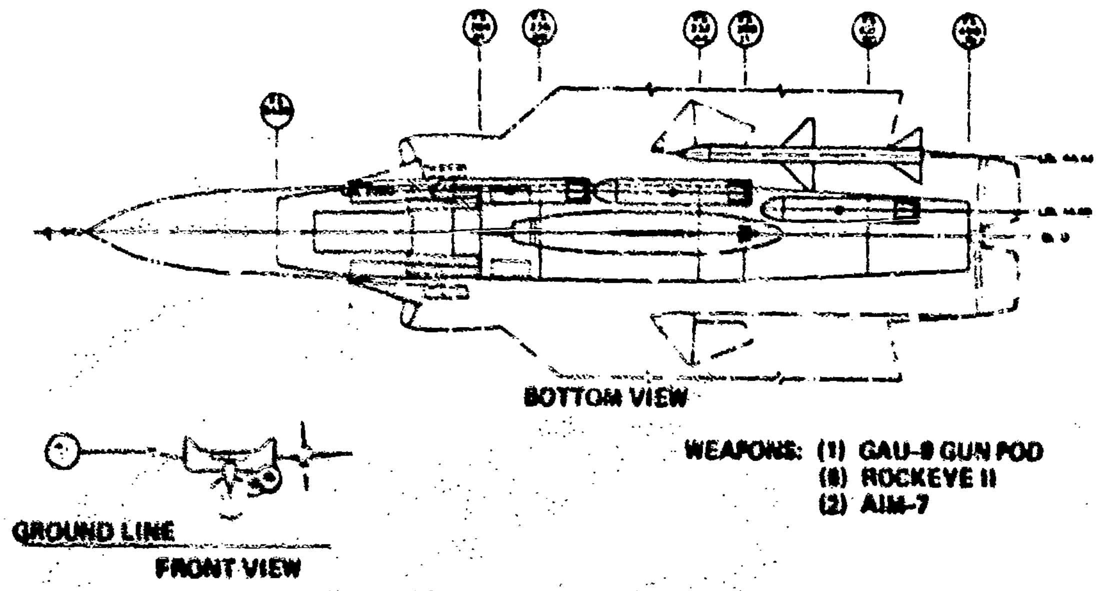


Figure 12. Weapon Arrangement F-4B/J

Table VI summarizes the weapon suit for the F-4E.

TABLE VI. F-4E Conformal Carriage External Stores

STORE	QUANTITY INSTALLED: DESIRED BY AFATL	QUANTITY INSTALLED: FEASIBLE		
MK-82	12		12	
MK-82	6	8		4
+			or	
BLU-27	4	2		3
MK-82	6	8		
+				
CBU-58	6	4		
LAU-61	9	6		
MK-82	6	9		
+				
SUU-25C/A	2	2		
SUU-45	5	4		2
+			or	
MK-82	4	3		8
B-43	2	3		
B-57/61	4	3		
MK-84EOGB	4	2		
AGM-45	4	3		
+				
AGM-78	2	-		
AGM-45	4	-		
+				
CBU-58	6	8		
AGM-78	2	-		
+				
CBU-58	6	8		
MK-20 MOD 0	-	11		
CBU-38	-	11		
ASP	-	8		

TABLE VI (Continued)

STORE	QUANTITY INSTALLED	
	DESIRED BY AFATL	FEASIBLE
AGM-65	6	6
MK-84LGB	4	3
+		
Pave Spike	1	1
MK-82LGB	6	5
+		
Pave Spike	1	1
CBU-58	6	6
+		
SUU-25C/A	2	2
SUU-51	-	8
SUU-45	-	5
ASP	-	6 or 3
+		
MK-82	-	4 or 8
BLU-27	-	2
+		
CBU-58	-	4
LAU-10	-	3
LAU-69	-	3
CBU-72	-	6
LAU-10/LAU-69	-	2
+		
MK-84EOGB	-	1
MK-83LGB	-	3
+		
Pave Spike	-	1
LAU-69	-	2
+		
MK-20 MOD 3/APAM	-	5
CTU-1	-	3

TABLE VI (Continued)

STORE	QUANTITY INSTALLED DESIRED BY AFATL	FEASIBLE
SUU-44/SUU-40	-	4
BLU-27 +	-	2
MK-20 MOD 0	-	5

The fins on SUU-45 must be folded to permit carriage tangent to a surface. Wing stations 2 & 8 are available for additional weapon installation at the expense of drag and stability.

A matrix of ejector locations was developed for the weapon suits given in Tables IV and VI to minimize rearming time. Necessarily no single ejector pattern maximizes the number of weapons carried in each of the many weapon suits. Some compromises are required. The ejector location pattern developed is shown in Figure 13 and is considered optimal for the weapon suits given in Tables IV and VI.

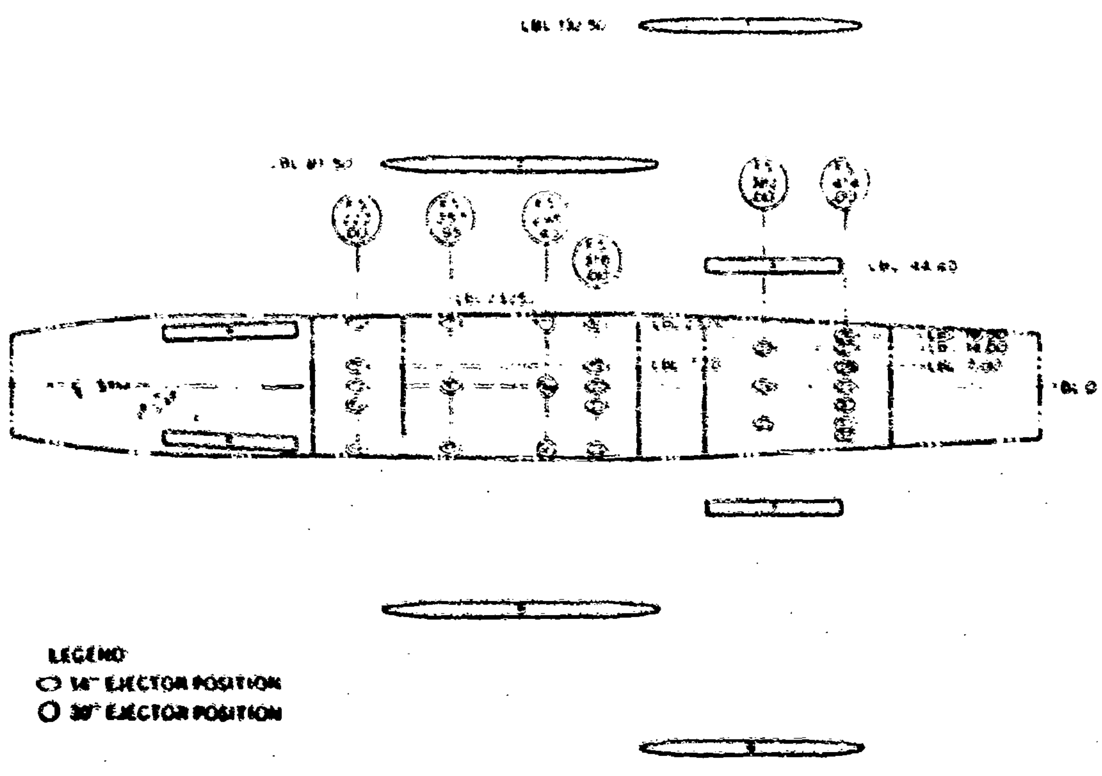
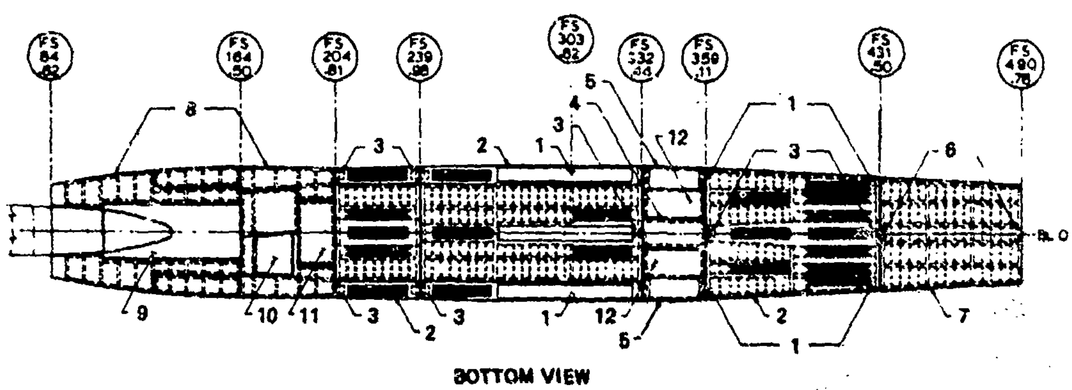


Figure 13. Weapon Stations

Besides the catapult bridle attachment hooks on the F-4 B/J the navy aircraft also include a catapult holdback fitting. The fitting is located on the keel beam near F.S. 439 and when used projects through the conformal carriage aft fairing region. The fitting assembly must be modified with a new link and snubber which absorbs the shock loading associated with rupture of the "dogbone" fitting during catapult launch.

Quick turnaround and maintenance access requirements dictate a structural arrangement permitting palletized loading of weapons on to the aircraft. Two choices were investigated; an external pallet where the weapons are loaded onto the conformal carriage with the pallet used as a lifting platform, and a segmented conformal carriage where weapons can be loaded onto a portion of the conformal carriage and the entire assembly quickly attached to the aircraft. This latter choice offered the best compromise between structural integrity, quick turnaround arming time, maintenance access, and installed conformal carriage weight. The arrangement used is shown in Figure 14.



1. SWAY-BRACE FITTING LATERAL WEAPONS LOAD
2. PLUG-IN MAIN STRUCTURE, WEAPONS LOAD
3. QUICK RELEASE FITTING, MAIN STRUCTURE TO AIRPLANE ATTACHMENT
4. MAIN CENTERLINE FITTING
5. SLIDING AUXILIARY AIR DOOR
6. FITTING, AFT FAIRING ATTACHMENT
7. AFT FAIRING (REMOVABLE) 9 FT^3
8. FORWARD FAIRING 11 FT^3
9. NOSE LANDING GEAR DOOR, CWC
10. LOX FILL SLIDING ACCESS DOOR
11. LOX CONVERTER ACCESS DOOR
12. CWC ENGINE ACCESS DOOR

☐ = SPACE FOR 30" WEAPONS EJECTOR

■ = SPACE FOR 14" WEAPON'S EJECTOR

Figure 14. Structural Arrangement

Built-in hoisting systems were incorporated in each of the conformal carriage bays. The motive power for the hoist units is external to the conformal carriage to minimize cost and OEW. Any form of rotational power can be used from an electrical motor to a man with a speed wrench. Figure 15 illustrates the detachable nature of the conformal carriage modules. Loading and arming of weapons and weapon ejectors are shown in Figures 16 and 17. The ejectors are armed after the weapons have been locked in place and before the assembly is hoisted onto the aircraft. Safety considerations on airfields and aircraft carriers dictate this sequence of aircraft arming. The quick disconnect and reconnect feature of the conformal carriage weapon modules is provided by special manually operated structural attachment fittings which can be quickly opened or closed and locked. Sufficient length of umbilical cord is required to permit electrical hookup and checkout before the conformal carriage weapon module is hoisted into final position.

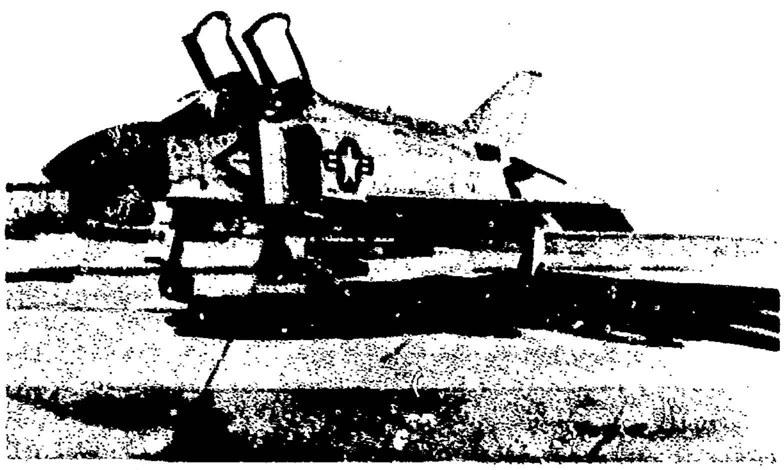


Figure 15. Conformal Carriage Modules

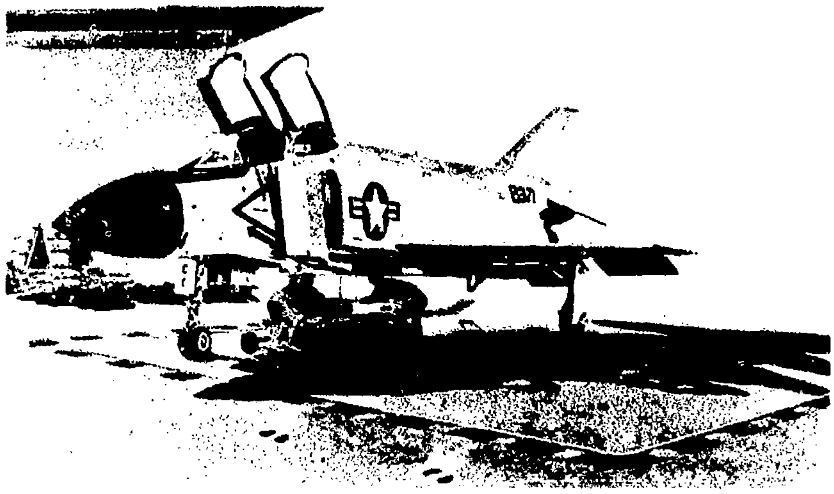


Figure 16. Ordnance Loading on CVA

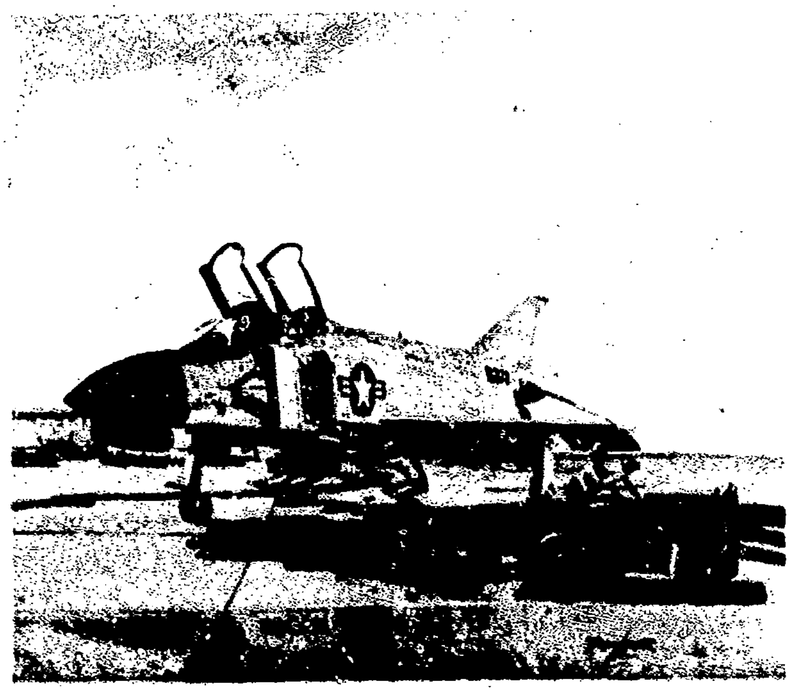


Figure 17. Ordnance Loading on Tactical Base

Figure 18 depicts a catapult launch of a conformal carriage F-4J loaded with MK82 bombs. The envelope of motion for the catapult bridle as the bridle rings come off the catapult launch hooks is a critical weapon clearance problem, which has been solved for the weapons given in Table IV.

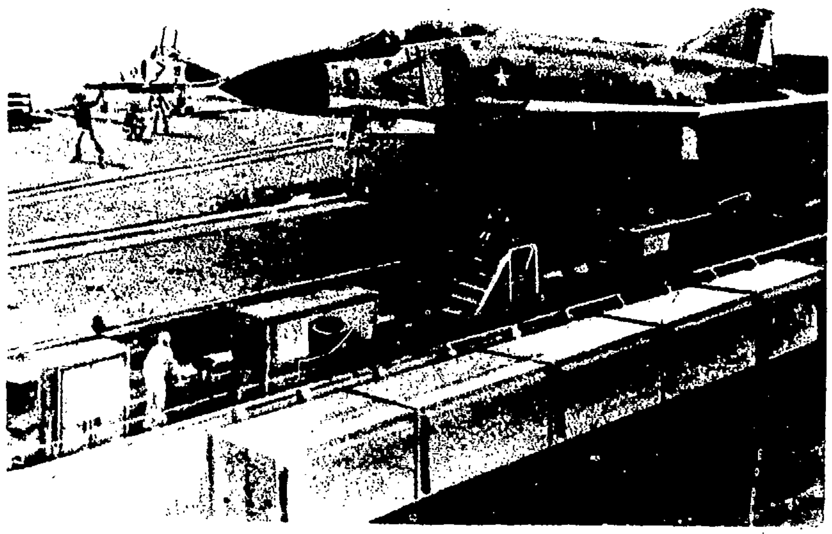


Figure 18. Catapult Launch Conformal Carriage F-4J

Analysis of the F-4 servicing sequence indicates some changes in sequence will be required with conformal carriage F-4's.

Detailed changes in servicing procedure maintenance card deck etc., are given in references 8 and 9. The impact of the conformal carriage installation upon servicing time will be minimal for both the F-4 B/J and the F-4E.

WEAPON EJECTORS

A key element in deployment of operational conformal carriage technology on any aircraft is the weapon ejector to be utilized. At the present time no ejector in the inventory is totally satisfactory. Several designs can be readily modified to satisfy functional requirements in a conformal carriage. The special peculiarities of a conformal carriage installation are:

1. Ejector rearming should be possible through either top, bottom, or sides of the ejector. Preferable location for the F-4 conformal carriage is at the top centerline of the ejector.

2. The manual release mechanism must be such that it can be operated within the .5 inch portion of the ejector projecting from the conformal carriage lower surface.

3. Secondary release provisions must be incorporated in the ejector. Jettison of the ejector itself from the conformal carriage may be acceptable although not desirable. Preferably the normal release mechanism should include some means of jettisoning the attached weapon if the primary ejection mechanism fails to function.

4. Swaybracing should either be internal to the ejector or should automatically retract when the weapon has been released. The bracing system can either use the bomb lug sides and top, the lugs and the bomb case, or the special lugs required in the "T" lug and saddle/spigot concepts. The swaybracing must be self adjusting to the weapon so that manual adjustment is not required. There is inadequate clearance for manual tightening of sway brace feet in a conformal carriage installation.

5. The energy source for the ejector should either be non-corrosive, non-contaminating in nature or the ejector must be capable of being quickly and completely cleaned without removal from the conformal carriage.

6. The ejector safing pin must be manually removable from the .5 inch protruding portion of the ejector or must be an inflight operable ejector lock.

ADDITIONAL CAPABILITIES

The F-4 conformal carriage design provides unused volume within the forward fairing and the aft fairing as well as within the removable weapon support modules. The volume within the forward fairing can be used for installation of internal ECM equipment. Simulated conformal carriage installations of horn and multibeam array ECM antennas were tested by an ECM vendor on an over-water range to determine their relative merits in a conformal carriage installation. Figure 19 illustrates the field of view for a typical horn antenna installed along one side of the conformal carriage in an external pod. Figure 20 depicts the radiation pattern intensity variation with azimuth in the -10° elevation plane for the typical horn antenna.

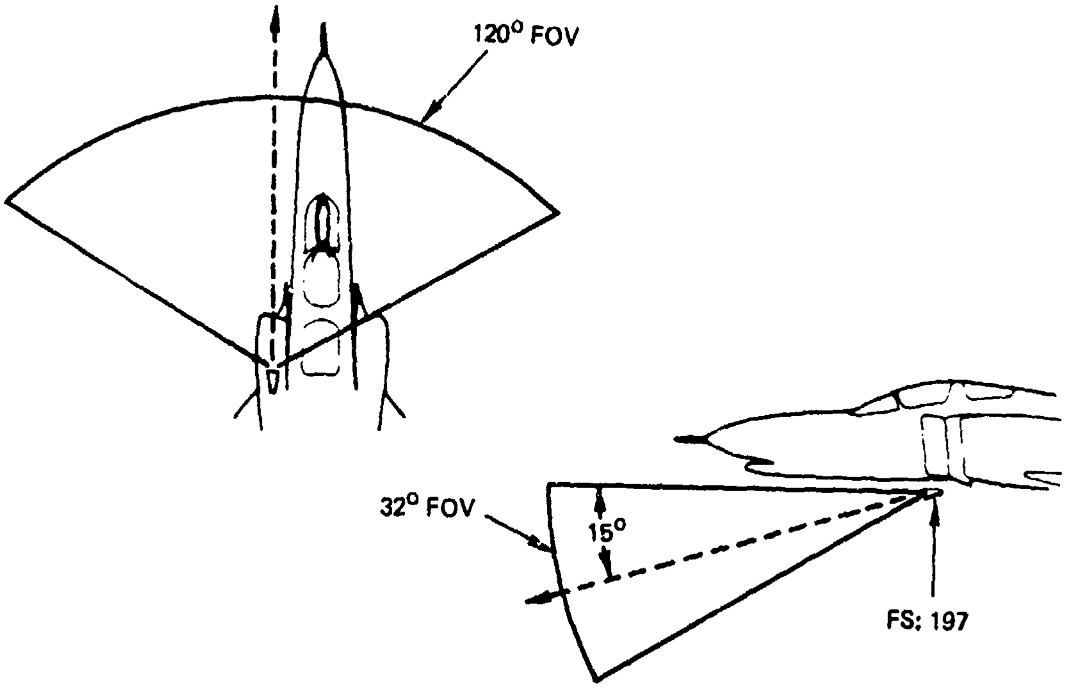


Figure 19. Horn Antenna Field of View

FREQ: 10 GHz
POL: H
GAIN: 5 DBI
ANT. BORESITE
SQUINT:
AZ: 0°
EL: -15°

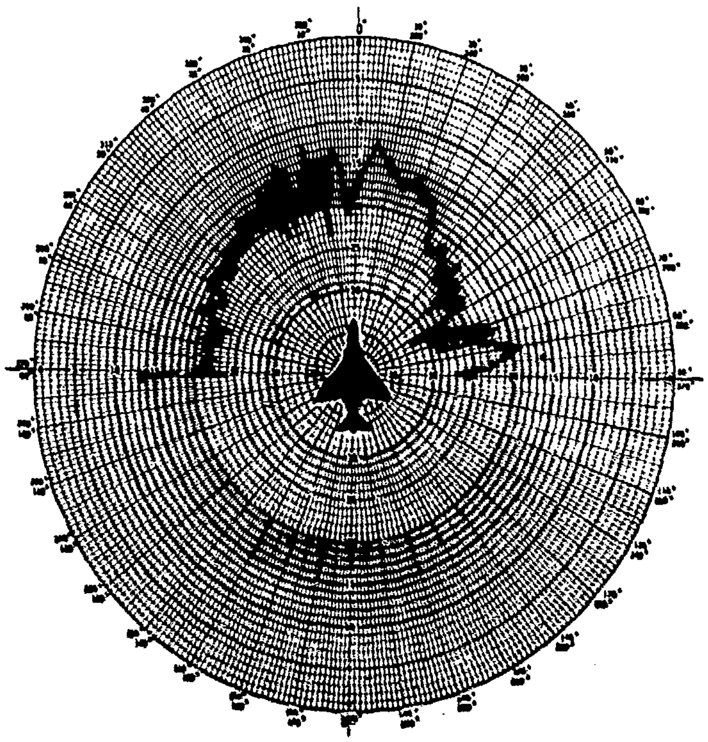


Figure 20. Horn Antenna Radiation Pattern

A multibeam array antenna was tested in a position compatible with a conformal carriage installation. The antenna was aligned 50° to one side in azimuth and down 20° in elevation. The field of view obtained is shown by the lightly shaded area in Figure 21. The radiation intensity variation with azimuth in the -10° elevation is shown in the lightly shaded portion of the pattern in Figure 22. Had a similar antenna been installed in a mirror image position there would have been a 20° pattern overlap directly ahead of the aircraft. The overlap area is heavily shaded in Figures 21 and 22. Careful design to minimize undesirable effects in the 20° area directly ahead of the aircraft would be required for this type of installation.

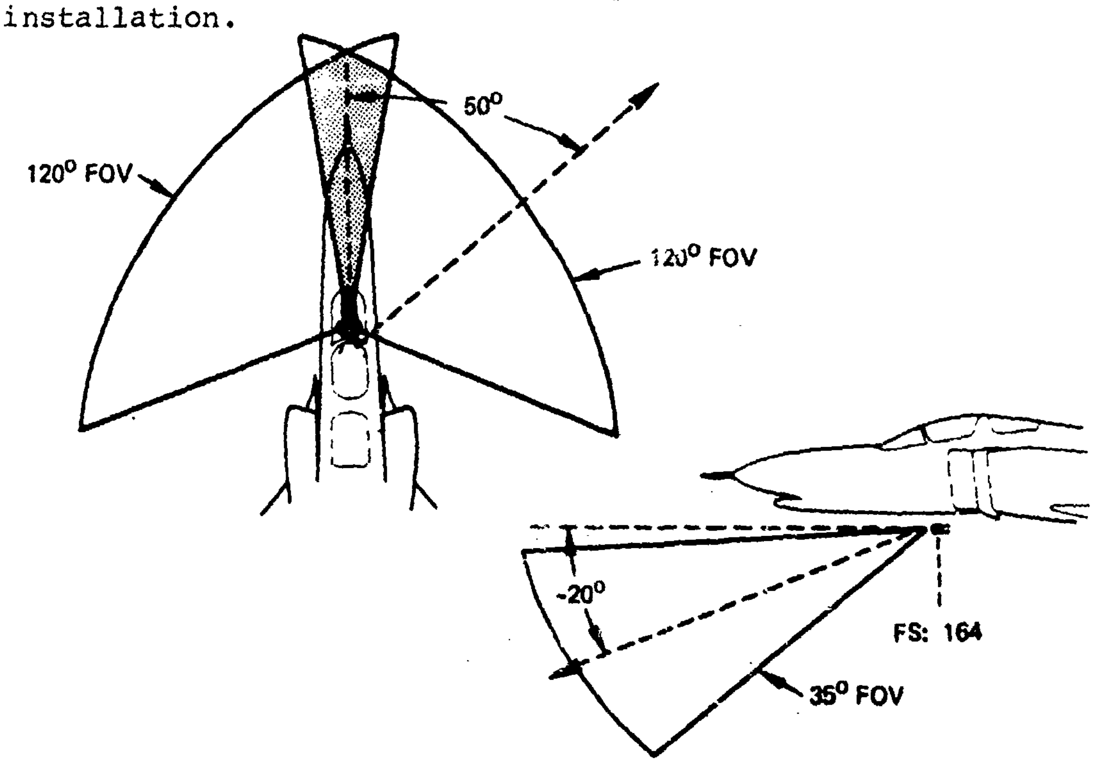


Figure 21. Multi-Beam Antenna Field-of-View

Installation of ECM capability within the low drag conformal carriage can enhance the survivability of the aircraft by reducing its electronic image cross section without a decrease in aircraft performance.

Passive defensive systems can be installed in the conformal carriage aft fairing in a low drag configuration. Typical of these systems are the AN/ALE 40 chaff and flare dispensers. The conformal carriage installation would provide less drag and better scattering of the chaff with less impingement in the horizontal tail than the presently authorized inboard pylon installation.

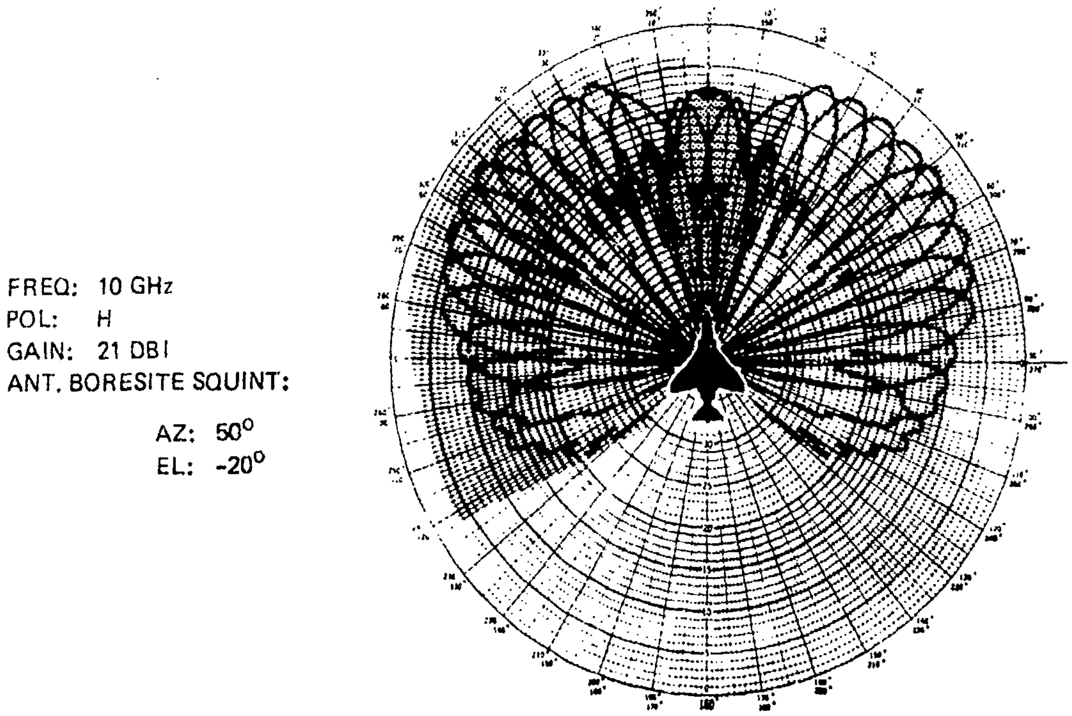


Figure 22. Multi-Beam Antenna Radiation Pattern

In addition to these defensive systems the conformal carriage can include necessary elements of the JTIDS system if desired. This system is a highly sophisticated communication network which is now in development. Among its important features are: secure data link, position location capability within 200 ft., information interchange with all elements of the network including AWACS, ground forces, and air forces.

VULNERABILITY ASPECTS OF THE F-4 CONFORMAL CARRIAGE

Installation of the conformal carriage under the F-4 fuselage covers a 52 in. wide strip centered on the aircraft centerline. The additional structure contains beams, ejectors, and skin panels with an average thickness of $\bar{T}$ = .6 in.

The engine cavity is approximately 90 inches wide therefore, the conformal carriage provides additional protection over 57% of the bottom of the engine cavity. During the attack phase of the mission the bombs under the conformal carriage provide additional heavy material through which projectiles must penetrate in order to reach the engine cavity.

The conformal carriage forward fairing covers the pneumatic compressor, the LOX converter, and the utility hydraulic accumulator reservoir; therefore, additional protection for these systems is provided by the basic conformal carriage with the option of adding armor plate inside the fairing if desired.

Another less quantifiable vulnerability aspect of the F-4 conformal carriage is the ability to penetrate and attack at higher speeds. Although the existing F-4 weapon management system is inadequate for accurate supersonic weapon delivery that capability could be available with installation of advanced avionics.

The low drag ECM installation possible with the conformal carriage also enhances aircraft survivability in that the aircraft maximum speed is not restricted by presence of the ECM equipment.

Integration of these possible system improvements in a conformal carriage installation not only increases the F-4 survivability but also greatly expands weapon carriage and delivery envelopes.

CONFORMAL CARRIAGE DESIGN METHODOLOGY

Ideally the design of a high performance attack system begins with definition of the targets to be attacked and the defenses expected to be encountered. From these two definitions, the weapon list and required flight envelope are developed. Once the weapon suits and flight envelope have been defined, the parent vehicle can be configured. Historically the ground attack role has devolved upon existing aircraft primarily designed as air to air rather than air to ground vehicles and consequently the above idealized development process cannot generally be adhered to. The difference between applying conformal carriage design methodology to new and existing aircraft designs primarily lies in the aircraft maintenance area and in weapons/aircraft integration.

The initial step in either case is development of weapon suits. Assembly on a "light table" of a montage composed of transparent scale drawings of weapons in types and numbers required minimizes the effort necessary to develop a composite weapon ejector location pattern.

Superposition of the weapon ejector location pattern upon the maintenance access requirements for an existing aircraft provides the data for design choices between changing aircraft service access requirements, service/rearming order sequence, ejector location pattern, or some combination of all three. The latter choice is usually the optimal system performance choice for modifying existing aircraft designs to conformal carriage systems. Obviously design of a new aircraft system can be developed around the weapon suits to be carried.

Rapid turnaround requirements may dictate a package loading concept in which a structural element of the conformal carriage could be loaded with weapons independently of the aircraft and subsequently quickly interchanged with a similar element from which the weapons have been expended. Attachment of the structural assembly to the aircraft must then be simple, reliable, and self aligning. The optimal method appears to be a hoist assembly integral with the conformal carriage module and separate external power source usable for loading/unloading many aircraft.

An ideal gear train concept for such a hoist is the harmonic drive system developed by United Shoe Machinery Corporation. Final attachment of the removable conformal carriage structural modules to the aircraft should be over center latches similar to weapon ejector hooks with alignment pins to transmit horizontal shear loads across the conformal carriage/aircraft interface. The alignment pins should be conical and fit into conical holes to provide precise alignment of the conformal carriage modules with the aircraft. They could also serve as master locating points for factory assembly of the conformal carriage modules.

The electrical interface between the aircraft stores management system and the conformal carriage could be an umbilical cord for each removable conformal carriage module. The aircraft stores management system must be programmable to release the weapons in one of several sequences to provide sufficient tactical flexibility. Generally release should begin with the aft most weapon in a given sequence. Intervals between releases from a conformal carriage may be as low as 15 milliseconds without weapon to weapon collisions. Such rapid release may be mandatory in supersonic attacks since at Mach 1.5 at sea level and a standard day the longitudinal distance traveled between 15 millisecond weapon releases is 25 feet.

The advent of guided glide bombs with large wings poses conformal carriage problems peculiar to this type of weapon. Either small pylons must be added to the conformal carriage surface, the weapon wings folded, or the conformal carriage surface specially shaped to adapt to the weapon cross section. Drag data indicate small pylons on a conformal carriage are preferable to wing pylons for carriage of these large wing span weapons. The maximum aircraft speed capability is only attainable through true conformal carriage of these weapons by wing folding or by specially shaped conformal carriage surfaces. The solution chosen for the operational conformal carriage F-4 is weapon wing folding rather than special shaping of the conformal carriage.

Figure 23 depicts the operational conformal carriage F-4E as deployed to a TAC base.

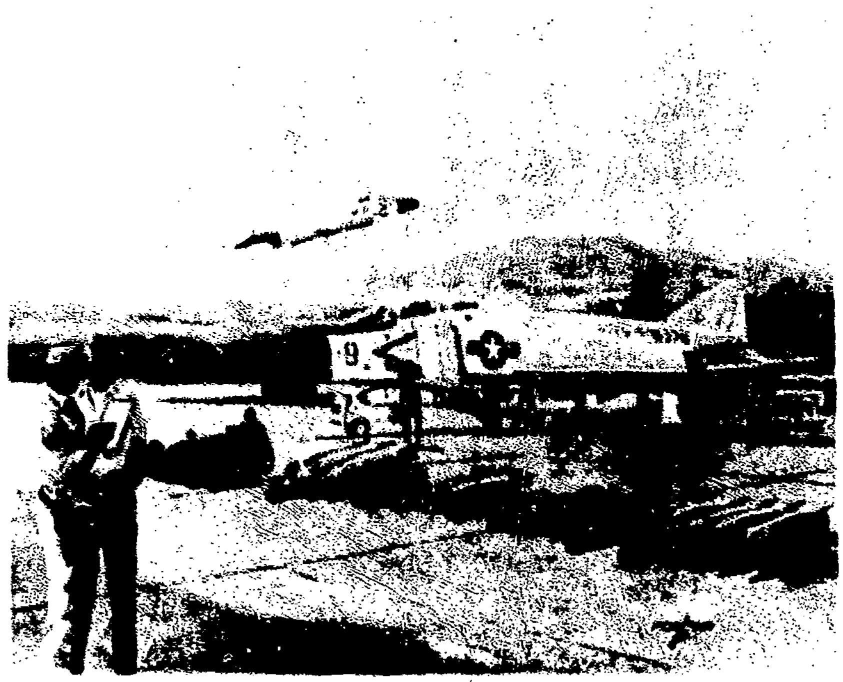


Figure 23. Operational Conformal Carriage F-4E

ALL WEATHER SUPERSONIC ATTACK AVIONICS

The changes required in the F-4 avionics system to provide all weather supersonic attack capability and to exploit the performance gains provided by conformal carriage are listed in Table VII. All of these items are required by F-4 ROC 12-72 and would be satisfied by the capability inherent in the AN/ARN-101 system. Additional capability could be obtained through incorporation of the items given in Table VIII. True supersonic attack capability for the F-4 cannot be obtained through incorporation of the items in Table VII unless the aircraft is modified to a conformal carriage configuration or the external stores are limited to only those carried on the fuselage.

TABLE VII
F-4 ROC 12-72 Avionics Changes

1. ASN-46 Navigation Computer

2. LN-12 Inertial System

3. ASQ-91 Ballistic Computer

4. ASG-22 Optical Display Unit

5. Associated Controls & Displays

Items 1 through 5 could be replaced by AN/ARN-101 installation which integrates items 6, 7, and 8 into a single system.

6. LORAN Navigation System

This system is an integrated LORAN/inertial-prime sensor system and includes the capability for bombing in both visual and all weather conditions. Release points can be determined through Radar, LORAN, Inertial, and LORAN Inertial Navigation and Bombing methods. In addition this system includes capability for continuous computing the impact point (CCIP) Dive, Dive-toss, and offset bombing modes. It also accepts input data from the air data computer, fire control radar, and optical target trackers such as TISEO, Pave Penny and Pave Spike. The expected weapon delivery capability of this system for visual low speed subsonic releases is 7 mils or better provided the weapons are released singly from each aircraft store station. The errors induced by sequentially releasing weapons from the same pylon store station can be very great due to the elastic behavior of the pylon from which the store is released.

7. Digital Inertial Navigation System

The digital I.N.S. is a highest state of the art system with expected drifts less than 1.0 NM/hr for LORAN Navigation System Sensors.

8. Digital Computer

This equipment may [illegible] the computation functions for the LORAN Navigation System and Weapon Delivery sequence. It requires low input power and has hard memory capability, read/write capability and can be readily doubled in storage capacity.

TABLE VIII
Additional Improvements Feasible for F-4

1. Improved Air Data Computer with higher accuracy velocity measurements for low altitude high speed flight.

2. Electronic HUD

Improved displays for precision weapon delivery at supersonic speeds.

3. FLIR

Provides visual search and target acquisition capability at night.

4. Improved Radar Bombing Capability

Higher performance and resolution radar for weapon delivery under all conditions except extremely low altitude.

5. Terrain Following/Terrain Avoidance (TF/TA)

This equipment is necessary if the extreme low altitude missions are to be performed by the F-4.

6. VTAS/TISEO System

Slaving TISEO to VTAS (Helmet mounted sight) will enhance system performance when attacking targets of opportunity.

7. DAIS Stores Management Technology

The existing F-4 stores management system is not a digital system and could be replaced by a system more compatible with the digital equipment in AN/ARN-101.

The improved capability inherent in Table VII items may be incorporated in the existing F-4 fleet before the aircraft become obsolete while the more developmental nature of the Table VIII items might preclude their operational use in the F-4's.

A preliminary design for a high performance strike fighter using conformal carriage methodology is illustrated in Figure 24. The bottom of the aircraft is contoured to provide conformal carriage of the weapons shown in Table IX. The design weapon suits were items 1 through 6 which set the ejector location pattern. Addition of 4 oblique mounted 30 inch ejectors permits a maximum weapon load of 6 MK-84 bombs. Weapon Suits 7 through 15 also fit within the ejector matrix.

TABLE IX
Advanced Strike Fighter Weapon Loads

1. Condor and Pod
2. 2 MK-84 Laser Guided Bombs
3. 2 Extended Range Walleye II
4. 9 Rockeye II or APAM
5. 9 MK-82 Bombs
6. 6 MK-83 Bombs
7. 6 MK-84 Bombs
8. 2 Harpoon
9. 5 MK-77 MOD 4 Fire Bombs
10. 5 CBU-72/B FAE Bombs
11. 6 SUU-30 Dispensors
12. 6 ASP
13. 4 MK-82 Laser Guided Bombs
14. 4 MK-83 Laser Guided Bombs
15. 2 MK-84 EO Guided Bombs

The lower surface is configured to accept two AIM-7 Sparrow missiles instead of bombs for an air to air mission.

The aircraft structure is arranged around the weapon ejector pattern to provide minimum structural load paths. The aircraft is also designed for servicing through the nose wheel well and the body side to avoid interference with weapon loads. The aft weapon ejectors are supported on a removable structure which is unbolted for engine removal. Figure 25 illustrates the structural arrangement, the armament stations and the aircraft service points while Table X lists the design data. The projected performance of this vehicle is compared to that of an A-7 in Figure 26. The impact of conformal carriage technology

on the payload range curve for an advanced strike fighter is evident in Figures 27 and 28. At short ranges, aircraft drag is unimportant and wing mounted multiple weapon stations are optimal. As mission ranges increase weapons must be traded for fuel and soon the lower drag of conformal carriage dominates the payload range calculations.

TABLE X
Advanced Strike Fighter

Geometry	Wing	Vertical Stabilizer	Horizontal Stabilizer
Area (Sq Ft)	518.3	69.1	73.2
Aspect Ratio	3.09	1.06	2.53
Taper Ratio	0.21	0.20	0.22
Sweep @ C/4 (Deg.)	38.0	34.5	26.5
Incidence (Deg.)	2.0	0.0	0.0
Dihedral (Deg.)	0.0	0.0	10.0
Root t/c (%)	5.5	5.5	5.5
Tip t/c (%)	3.5	3.5	3.5
Root Chord (Inches)	258.0	161.0	106.0
Tip Chord (Inches)	53.0	33.0	23.0
MAC (Inches)	178.02	111.08	73.40
Span (Feet)	40.0	8.54	13.62
Tail Arm (Inches)	--	181.5	236.2
Tail Vol Coeff.	--	.054	.187
T/c @ MAC	3.5	3.5	3.5

Flap Area	34.7 Sq Ft
Flaperon Area	55.6 Sq Ft
Speed Brake Area	148.0 Sq Ft
Rudder Area	19.8 Sq Ft

Operating Weight	24,400 Lbs
Armament Max.	13,810 Lbs
Internal Fuel Max.	15,800 Lbs
Max T.O. Gross Weight	47,41? Lbs.
Propulsion F-101-100	30,000 S.L.S.T.

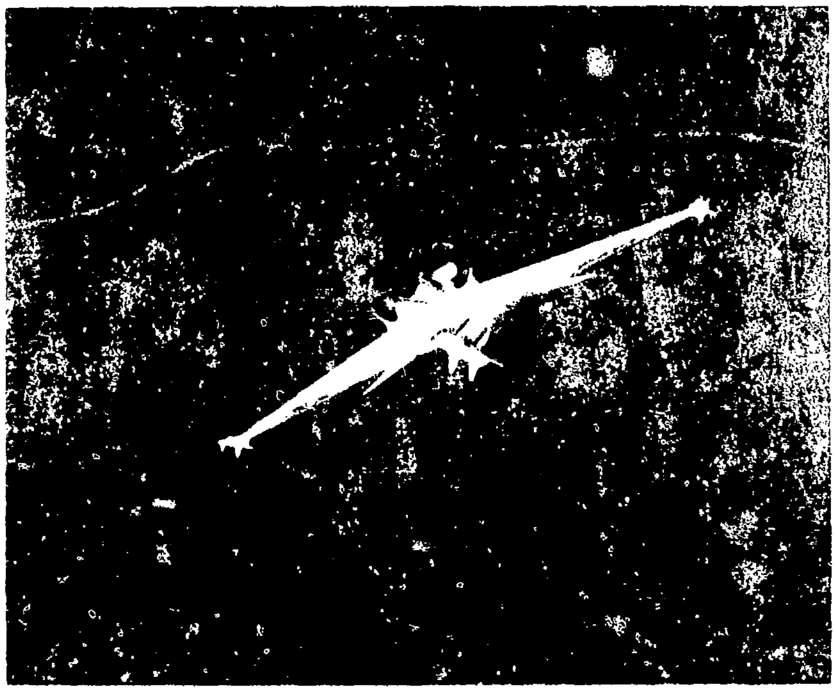


Figure 24. Advanced Carrier Attack Fighter

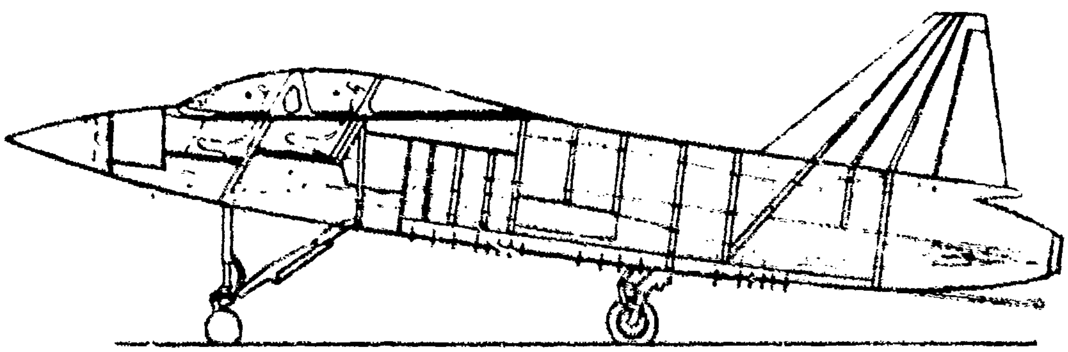


Figure 25. Structural Arrangement Advanced Carrier Attack Fighter

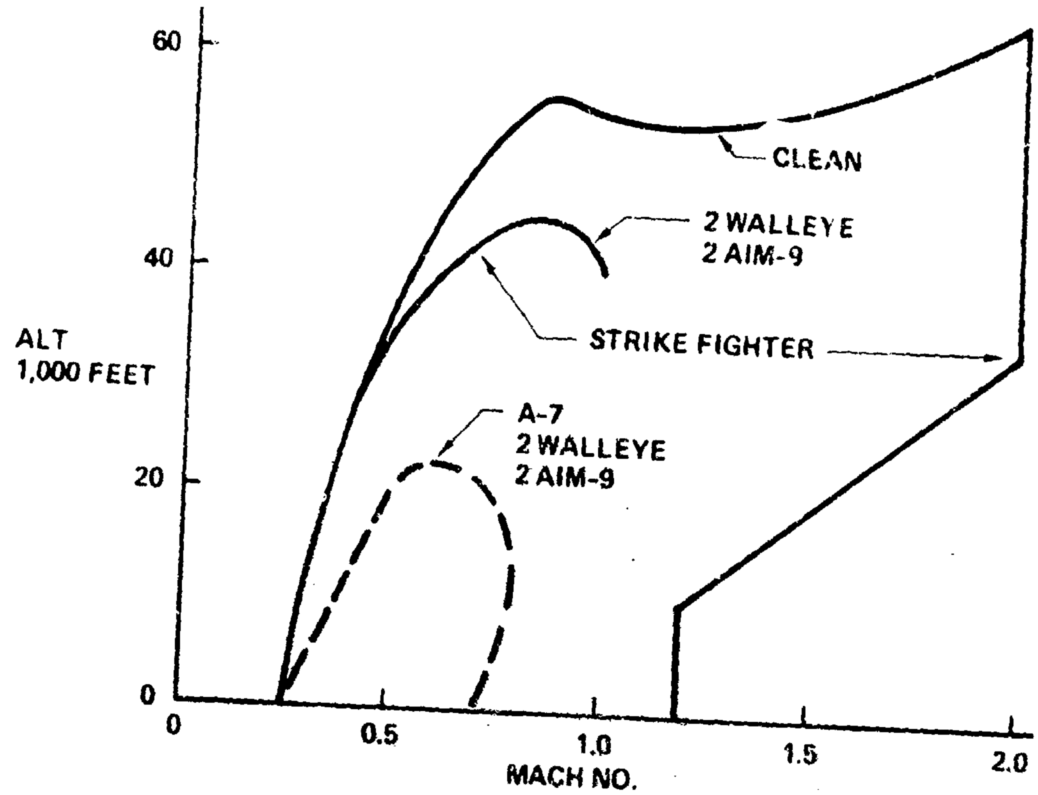


Figure 26. Advanced Strike Fighter Performance

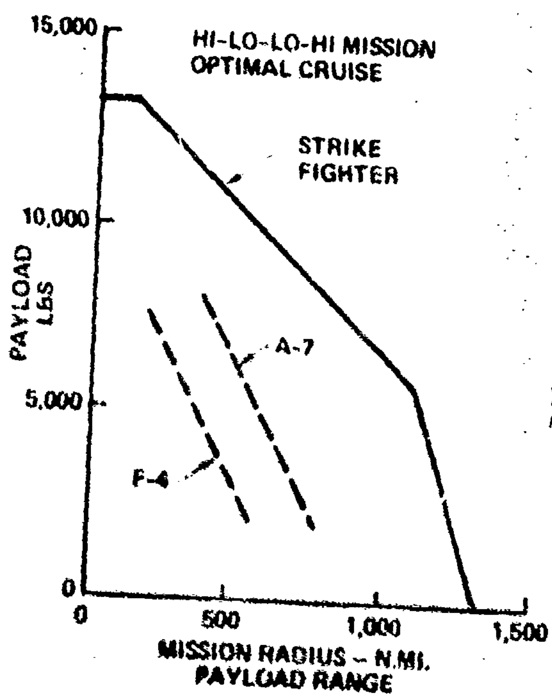


Figure 27.

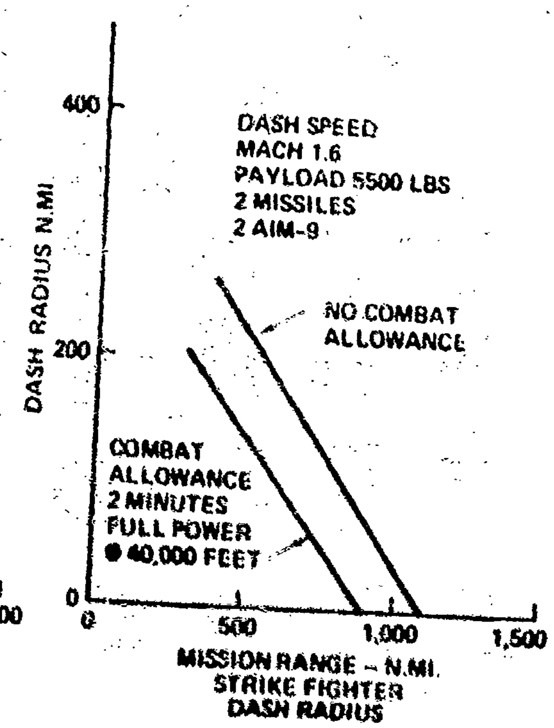


Figure 28.

CONCLUSIONS

Conformal carriage is considered a mature technology as applied to the F-4. Further engineering development for the F-4 conformal carriage is unnecessary. Applications of the technology to other existing designs such as F-5, F-14, F-15, F-16, F-18, and Mirage F-1, and Jaguar requires development work and engineering design studies prior to production modification. The technology will undoubtedly be incorporated in all new high performance long range attack aircraft. Although intrinsically the same, each such application will be unique due to the diversity in engineering teams throughout the industry. However, all new designs will benefit from the use of this technology.

Operational use of supersonic weapon delivery techniques will require development of supersonic weapon ballistic data which therefore implies actual supersonic weapon releases. Presently aircraft capable of releasing external stores at speeds above 1.3 in level flight are not available for use in acquiring the necessary ballistic data and will be required before the operational use of the expanded flight envelope can be exploited.

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10. Conformal Carriage Separation Program

AUTOBIOGRAPHY

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Mr. Zapel received a B.S. in Civil Engineering and an M.S. in Engineering from Gonzaga University in 1952 and an M.S. in Civil Engineering from University of Washington in 1962. He was employed in Lockheed Corporation's Structural Test Laboratories of Burbank, California from 1952 to 1954 when he moved to The Boeing Company. He has made significant contributions in design of high temperature structural test equipment, material test specimens, and test methods. He has extensive experience in theoretical and experimental stress analysis and also in applying experimental test results to design improvement. His experience includes both analytical and design work in fracture mechanics, structural dynamics, aero-thermal-elastic structures, and also advanced vehicle configuration development including structural design.

Since 1970 he has been Chief Engineer for the F-4 Conformal Carriage program at The Boeing Company.

He is a Professional Engineer registered in the State of Washington.

OBJECTIVES OF THE
AGARD F.D.P. WORKING GROUP ON
DRAG AND OTHER AERODYNAMIC
EFFECTS OF EXTERNAL STORES

(U)
(Article Unclassified)

by

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England.

ABSTRACT (U)

Considerable work has been done in the U.K. towards reducing the drag of external stores, but there are limits to the data that can be produced, or the improvements that can be made in any single country of NATO. Following a suggestion by the U.K. Ministry of Defence, the Fluid Dynamics Panel of AGARD set up a Working Group which now has members from seven countries (with representatives from the FMP and SMP) to report on the drag and other aerodynamic effects of external stores. This group is compiling recommendations on: drag, flying qualities, delivery accuracy, structural integrity, performance and manoeuvrability, for a report to be issued by the end of 1976.

This work has been carried out with the support of Procurement Executive, Ministry of Defence, United Kingdom

INTRODUCTION

When I was working on the basic design philosophy for the wing of the "Harrier" VTOL fighter I was trying to determine the relative importance of different features, so as to be able to devise the best wing. We may wish to reduce the weight and drag of the wing, improve manoeuvrability and so on - but as usual improving one feature may worsen another (for example increasing the wingspan to improve manoeuvrability increases the weight, and fitting leading-edge droop would increase cost). How does one balance drag against weight, ride quality or cost? One is driven back to the aim of the game: effectiveness to cost ratio - even if these quantities are not always easy to predict. The same conclusion applies to the various effects of external stores, as we will see.

To any aerodynamicist who has struggled to optimise the wings of an aircraft by careful design and meticulous attention to detail, it can be galling to find that typical ground attack aircraft carry store drags of the same order of magnitude as the drag of the entire clean aircraft. So there has been considerable work towards reducing store drags.

Now, much more is known about reducing store drag (as well as other effects) some of which you will learn from Mr. Barry Haines, and we have the AGARD Working Group which is pooling the knowledge and work of seven countries in an effort to recommend to NATO how external stores (including their carriers) should be modified so our air forces will have more effectiveness and less cost.

AIMS AND APPROACH OF THE WORKING GROUP

Terms of Reference

The terms of reference adopted by the Working Group and approved by the AGARD National Delegates' Board are as follows:

"To study means for reducing the drag and other aerodynamic penalties associated with carrying external stores on both current and future aircraft, and thus improving their operational capability. To study the effects of externally carried stores on the aerodynamic and aeroelastic behaviour of the aircraft/store combination, including release. To review the status of the relevant technological areas, to assess future prospects and possibilities, and to identify promising areas for research and development".

It is intended to have the final report printed and delivered to the Military Committee of NATO before the end of 1976. The members of the Group are cleared to handle material classified NATO SECRET, but the classification of the report has not yet been decided.

Membership

The membership comprises three groups: (1) the chairman and 6 or 7 members nominated by Fluid Dynamics Panel members of participating countries, (2) two representatives nominated by the AGARD Flight Mechanics Panel and (3) two representatives of the AGARD Structures and Materials Panel. Individual members may change, and deputising arrangements are flexible, but at the moment the membership is as listed in figure 1.

Format of Report

The provisional format of the eventual report and the members who will compile and edit the chapters are shown on Figure 2. Apart from the introduction and conclusions, each chapter of the report will be in the nature of a critical review of the state of the art, leading to conclusions and recommendations for that part of the field. Adequate data will be quoted to illustrate each argument, but it is not intended that the report will contain a compendium of data.

ASSESSMENT OF BENEFITS

Each specialist working in his own area is liable to think (and probably correctly) that an improvement in the quality he looks after is "A GOOD THING": less drag, better stability, a more accurately predicted trajectory, and so on. However, difficulties arise when they try to get somebody else to invest money in achieving this new increase of effectiveness or reduction of overall cost.

"I have no doubt that your 'planes would fly better after the stores have been modified, but the stores on the shelves have cost a lot of money, and altering them will cost a lot more" is the sort of response one can imagine. Such a response is not unreasonable, so long as it is recognised that the whole idea of making improvements is to save money, and there must be some particular amount of improvement which will make it worthwhile to incorporate the modifications. Human nature being what it is, the man who wants the improvements made had better start talking in the right language: money. That is a bit tough, because no one has given the aerodynamicists any generally accepted conversion factors. Consequently we have to try to arrive at some approach for assessing the value of various sorts of improvements.

In Europe, at least, it is common to assume that the effectiveness should be assessed on the assumption of a short and intensive war (in which most of our aircraft are lost), while the costs are assessed on the assumption of peace-time training.

On this basis, the effectiveness relates to the number of targets destroyed, and the cost relates to the cost of aircraft, supplies and weapons lost or used up.

Going through the list of chapters, one may see that each feature considered can be related to targets hit or aircraft and weapons lost, in a variety of possibilities.

(It should be noted that in Europe the ground-attack role is regarded as primary). Reduced drag, for instance, could result in less cost of fuel in peacetime or, in wartime, greater range and therefore more target-opportunities, or shorter take-off distance for given range, or a lighter and cheaper new design of aircraft. Flying qualities affect the accuracy of weapon delivery and also attrition rates (both in practice and in war). Structural integrity affects accidental losses, the margins of mass built in to allow for ignorance, or the cost of computations or measurements to remove that ignorance. Performance and manoeuvrability affect attrition and the capability of turning to attack targets, as well as the area of potential targets.

<u>Drag Reduction</u>

To illustrate the problem of assessing drag reduction let us consider various ways of cashing the benefit of a typical realistic improvement: a reduction of 20% of the overall drag of an aircraft - plus stores configuration.

If this reduction were achieved on stores carried only on the outward leg of sorties, the fuel consumption is typically reduced by about 6%, while if it were made on permanently-carried stores or pylons the reduction of fuel consumption would be around 12% for a given short range. At present fuel prices these amount to roughly 1.3% to 2.6% of the cost of buying the aircraft - but it can be guessed that in the next 10 years or so fuel prices may triple in real terms.

If the reduction of drag were applied to increase the radius of action, the area coverage (and consequently the probable number of target opportunities) would be increased by about 12% to 24%. Alternatively, the drag reduction may be used to allow a higher penetration speed (by perhaps 0.05 Mach number). Attrition rates vary fairly sensitively with speed, and this increase of speed on the outward legs of sorties may allow perhaps 6% to 8% more missions before losing the aircraft.

Lower drag also implies more specific excess power for manoeuvring, and this will afford more capability of turning to attack targets and more capability of avoiding attrition.

In addition to the cost reductions and effectiveness increases just discussed, there are additional cost savings available at the time of designing a new aircraft. A few simple studies suggest that

designing for the reduced drag would reduce the mass, cost and lifetime fuel of the new aircraft by roughly 2% to 4%, in addition to the benefits previously discussed.

Clearly the improvements of effectiveness/cost vary according to when they are made, how much of the time they are carried, and whether they are applied to existing aircraft or new designs. Taking middle values for the ranges quoted, and fuel at double present costs, the improvement of effectiveness/cost ratio seems to centre around 31% for existing aircraft and about 34-37% for new designs. There will be room for argument about the magnitudes of the benefits discussed here - but it seems fair to claim that a 20% reduction in overall drag may lead to future improvements of aircraft effectiveness/cost ratio in the order of 30% or more.

The argument so far has not introduced the cost of modifications designed to secure the benefits discussed. At a guess, the entire stocks of external stores per aircraft costs around a quarter or a third of the cost of the aircraft, and the modifications considered could not cost more than a modest fraction of that amount - particularly for new build. It follows that there are substantial net benefits that could be achieved by drag reduction, particularly on new designs of stores and aircraft. Hopefully, the Working Group will produce recommendations which will clarify this situation further.

Accuracy of Delivery

In some circumstances the effectiveness of the air force is very sensitive to accuracy. For example consider a European ground-attack scenario, in which the attrition rate is high, demanding very low level attack at high speed. Under such circumstances the probability of destroying a small target with unguided bombs after a perilous outward run may be perhaps 5%. Clearly, any improvements of technique that raise the probability to 10% or 40% would multiply the effectiveness of the airforce for such missions by factors of 2 or 8 respectively.

Clearly there can be very big benefits for "smart" weapon delivery systems, and it seems reasonable to suppose that as time goes on the external stores will increasingly become "smarter", with all the aerodynamic implications. However, it is not necessarily the store itself that needs to get smarter - for there are many features of the aircraft/store combination that may degrade or enhance the capability of an aircraft to delivery weapons accurately: such as stability, control and gust ride on the way in; manoeuvrability in the target area; and release disturbances both to the aircraft and the weapon (remembering that there have been cases where guided weapons lost "lock-on" due to release disturbances).

The working group is not equipped to develop these notions into defined operational analysis techniques, but it is felt that without them the task of assessment would be very vague.

FUTURE PROGRAMME OF THE WORKING GROUP

The members of the working group are now planning their respective chapters. They are looking out for all ideas relevant to the recommendations they have to compile, both in their own countries and at meetings (such as this one) where the experts come to share their thoughts. By the middle of February next year, the members should have sketched out the main themes of their chapters. By the end of May (hopefully) a draft of the report should be emerging, which allows the summer for mutual editing.

The members have knowledge from their own working backgrounds, but forming knowledge and ideas can be like breeding plants that grow and adapt by feeding on other ideas, and sometimes a new variety emerges.

That is why we are here. That is why I have "flown a kite" to tell experts what we are trying to do. Like Benjamin Franklin, I hope to attract some high-voltage sparks to my kite - that will help to [illegible] our conclusions. The more ideas we receive, the more will our recommendations reflect them.

CURRENT MEMBERSHIP OF
AGARD WORKING GROUP ON:

DRAG AND OTHER AERODYNAMIC
EFFECTS OF EXTERNAL STORES

Nominated by:

1. AGARD Fluid Dynamics Panel

Chairman:	Mr. C.L. Bore	HSA (U.K.)	P.M.
Canada:	Dr. K.J. Orlik–Ruckemann	(NAE)	P.M.
France:	Mr. A. Coursimault	(STA)	
Germany:	Prof.Dr. J. Barche	(VFW-Fokker)	P.M
Netherlands:	Mr. J. Van Nunen	(NLR)	
U.K.	Mr. A.B. Haines	(ARA)	
U.S.A.	Mr. C.B. Mathews	(AFAL, Eglin)	
and	Mr. J.H. Nichols, Jr.	(NSRDC)	

2. AGARD Flight Mechanics Panel

Italy:	Dr. R. Mautino	(Aeritalia)
France:	Mr. P. Poisson–Quinton	(ONERA)
deputy	Mr. B. Costes	(ONERA)

3. AGARD Structures and Material Panel

Germany:	Dr.Ing. B. Laschka	(MBB)
U.S.A.	Mr. W. Mykytow	(AFFDL, WPAFB)

Figure 1 July 1975

REPORT of the AGARD Working Group on

DRAG AND OTHER AERODYNAMIC EFFECTS OF EXTERNAL STORES

PROVISIONAL FORMAT

Chapter		(Compiler/Editor)	
1. INTRODUCTION		(C.L. Bore)	
2. DRAG		(A.B. Haines and J.H. Nichols)	
	2.1 Measurement and prediction		
	2.2 Ways to reduce drag	2.2.1	individual store carriage
		2.2.2	multiple carriers
		2.2.3	position of carriage
		2.2.4	conformal carriage
3. FLYING QUALITIES		(A. Coursimault)	
	3.1 Stability and control		
	3.2 Buffet and stall effects		
	C.C.V. aspects would be discussed wherever appropriate		
4. DELIVERY ACCURACY		(C.B. Mathews)	
	4.1 Store separation trajectory	4.1.1	experimental techniques
		4.1.2	calculation techniques
	4.2 Aircraft unsteadiness		
5. STRUCTURAL INTEGRITY		(B. Laschka, aided by Dr. Chesta of Aeritalia).	
	5.1 Aeroelastics		
	5.2 Load prediction		
6. PERFORMANCE AND MANOEUVRABILITY		(J. Barche)	
7. CONCLUSIONS AND RECOMMENDATIONS		(C.L. Bore)	

Figure 2

BIOGRAPHY

Clifford L. Bore served an apprenticeship before going on to study aeronautical engineering at Queen Mary College (London University) - graduating B.Sc.(Eng) in 1951. Joined the R&D department of Hawker Aircraft (now Hawker Siddeley Aviation, Kingston) and became responsible for various topics in materials, structures and aerodynamic load prediction. Awarded the degree of M.Sc.(Eng) for a thesis on the prediction of fatigue life, in 1959.

In 1957 placed in charge of aspects of project aerodynamics such as air intake design, kinetic heating and wave drag. Became responsible also for wing design, on designs such as the P.1154 and the "Harrier". Now responsible for aerodynamics research.

Represents the U.K. aircraft industry on the AGARD Fluid Dynamics Panel. Chairman of the AGARD Working Group on "drag and other aerodynamic effects of external stores".

FLIGHT TEST HEAT TRANSFER MEASUREMENTS ON A PYLON MOUNTED STORE[1]
(Article Unclassified)

by

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ABSTRACT. (U) The performance envelopes of some present-day aircraft have been restricted by temperature limitations on the stores. A two-phase program is currently in progress to provide the technology required to expand aircraft/stores flight envelopes. The flight test phase of this project includes temperature and heat transfer rate measurements on a BDU-12 mounted on the inboard pylon of an F-111. These data will be used to substantiate the procedures for extrapolation of wind tunnel data to flight conditions. The extrapolation procedures are discussed as well as the test hardware and typical flight test results.

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[1]The research reported herein was conducted by the Arnold Engineering Development Center, Air Force Systems Command under sponsorship of the Armament Development and Test Center. Results were obtained by personnel of ARO, Inc., contract operator of AEDC. Further reproduction is authorized to satisfy needs of the U. S. Government.

NOMENCLATURE

c_p	Specific heat of air at constant pressure (≈ 0.24 Btu/lbm-$^{\circ}$R)
L	BDU length, in.
M_∞	Free-stream Mach number
n	Exponent in correlation parameter (see equation 4)
$\dot{q}$	Heat-transfer rate, Btu/ft^2-sec
$Re_{\infty,L}$	Free-stream Reynolds number based on BDU length (118.5 in. for flight, 7.9 in. for wind tunnel)
$Re_{\infty,x}$	Reynolds number based on free-stream conditions and x.
St	Stanton number, $\dot{q}/\rho_\infty V_\infty c_p (T_r - T_w)$
T_r	Recovery temperature, $^{\circ}$R or $^{\circ}$F as noted
T_o	Total temperature, $^{\circ}$R or $^{\circ}$F as noted
T_w	Model wall temperature, $^{\circ}$R or $^{\circ}$F as noted
T_∞	Free-stream static temperature, $^{\circ}$F
V_∞	Free-stream velocity, ft/sec
x	Longitudinal centerline distance from BDU nose, in.
ρ_∞	Free-stream density, slugs/ft^3
μ_∞	Free-stream viscosity, lbm/ft-sec
ϕ_{ray}	Circumferential position on BDU, deg (see Fig. 5)

SUBSCRIPTS

flt	Flight conditions
wt	Wind tunnel conditions

ILLUSTRATIONS

INTRODUCTION

At the first Aircraft/Stores Compatibility Symposium, Epstein (Ref. 1) discussed supersonic carriage of conventional weapons. He pointed out that the performance envelope of present-day aircraft can be severely limited by external stores as illustrated in Figure 1. Unfortunately, these limitations are sometimes imposed by "arbitrary temperature limits on the store". Most bombs and fuzes have, as their explosive charge, some form of TNT which melts at about 178°F. To avoid this possibility the aircraft speed is restricted. However, to predict the actual temperature of the TNT in flight, one must know the following:

1. The maximum temperature attainable (i.e., T_r, see Fig. 1) and the length of time at a given flight condition.

2. The rate at which heat is being transferred to the store (i.e., the heat transfer rate, $\dot{q}$).

3. The thermophysical properties of the store so that a heat conduction solution can be obtained.

Of these, the heat-transfer rate is the hardest to determine.

Within recent years, a wind tunnel technique has been developed to measure heat-transfer rates on pylon mounted stores. This technique is described in Ref. 2 and at the last Aircraft/Store Compatibility Symposium, Matthews, et al (Ref. 3) discussed the application of these wind tunnel results to actual flight conditions. Figure 2 is a schematic illustrating the extrapolation procedures. Determination of the proper aerodynamic scaling law is a vital link in these procedures. Theoretical considerations have been used to establish the scaling relationship to extrapolate from wind tunnel conditions to flight conditions. However, to substantiate this scaling relationship a research project is presently in progress at the von Kármán Facility (VKF) of AEDC under the sponsorship of AFATL. The scope of this project includes both flight tests and wind tunnel tests of a Bomb Dummy Unit (BDU) mounted on the inboard pylon of an F-111. The wind tunnel phase is being conducted in the 40 x 40-in. continuous flow tunnel of the VKF (Tunnel A). The flight test phase is being conducted at Edwards Air Force Base and is a "piggyback" effort connected with project DAME[1] (Determination of Aircraft Missile Environments). This paper discusses the work that is presently being done at Edwards in terms of theoretical considerations, experimental apparatus, and results to date.

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[1] Project DAME was originated by Mr. Leo Meyer and is presently being monitored by Lt. Michael Bond, AFRPL/MKMA.

THEORETICAL CONSIDERATIONS

A computer code for the solution of the store interference flow field is presently being developed at Lockheed, Huntsville. The complexity of the flow field was illustrated by the flow visualization photographs presented in Ref. 3. Because of the flow field complexity these theoretical calculations are extremely difficult. Conversely, the calculations of the flow field about a store in an interference-free flow field are relatively straightforward and can provide an insight as to the proper aerodynamic scaling law.

To investigate the significant parameters and to guide the experimental work, the Spalding-Chi turbulent heating method (Ref. 4) has been utilized. Calculation of the Stanton number distribution on the BDU were made for conditions corresponding to those of the wind tunnel test and for conditions corresponding to those of the flight test. These specific conditions are summarized below.

parameter	wind tunnel	flight
M_∞	2.0	2.0
BDU length, in.	7.90 (1/15 scale)	118.5
$Re_{\infty,L}$	6.32×10^6	47.2×10^6
T_W/T_O	0.75 - 0.96	0.60 - 0.96

The results of these calculations are presented in Fig. 3 in terms of $Re_{\infty,x}$. The effect of wall temperature variation is within the estimated precision of the experimental data and therefore this effect can be neglected.

The Reynolds number difference attributable to the relatively small model size can be correlated by use of the equation

$$St\,(Re_{\infty,x})^n = \text{const} \tag{1}$$

or

$$\left[St\,(Re_{\infty,x})^n\right]_{\text{wind tunnel}} = \left[St\,(Re_{\infty,x})^n\right]_{\text{flight}} \tag{2}$$

For turbulent boundary layers the classical value of n is 0.2 (i.e., 1/5). However, by utilizing the semi-empirical Spalding-Chi solutions, it is possible to determine the value of n for the specific conditions of current interest.

Consider a given nondimensional location on the BDU (e.g., x/L = 0.3). For this location

$$St_{flt} = St_{wt}\left(\frac{Re_{\infty}, x_{wt}}{Re_{\infty}, x_{flt}}\right)^n \tag{3}$$

Since the Reynolds numbers are known and the Stanton numbers can be obtained from the Spalding-Chi solutions, the only unknown in this equation is n. The best value of n for $0.05 \le x/L \le 0.45$ was determined to be 0.17 and the correlation obtained by using this value is illustrated in Fig. 4.

It should be emphasized that the above results are based on interference-free flow field calculations and the actual correlating equation developed from experimental data may be somewhat different than that shown in Fig. 4; however, the basic form should remain the same. That is

$$St_{flt} = St_{wt}\left(\frac{Re_{\infty}, x_{wt}}{Re_{\infty}, x_{flt}}\right)^n \tag{4}$$

where $n \approx 0.17$.

EXPERIMENTAL APPARATUS

As mentioned in the introduction, the flight test phase of this project is being conducted on a "piggyback" arrangement with Project DAME at Edwards AFB. Project DAME utilizes an internal data recording system to record inert propellant stress and strain data and some preliminary results of this project are presented in Ref. 5.

Additional instrumentation has been installed by AEDC/VKF personnel so that the heat transfer scaling law derived in the previous section can be substantiated. The location and type of instrumentation installed is illustrated in Fig. 5. The primary instrumentation consists of 13 heat gages. Each gage measures both the heating rate ($\dot{q}$, Btu/ft^2-hr) and the wall temperature. A detailed description of these gages and the data reduction technique is presented in Ref. 6. Secondary instrumentation consisted of coaxial surface thermocouples (described in Ref. 6) and backside thermocouples to measure the temperature differential across the "skin thickness" of the BDU. Also installed in the BDU was a pressure package for measuring the differential pressure in the pitch and yaw planes at $x/L = 0.05$. The purpose of these measurements is to obtain relative flow angularity data.

The data acquisition system is described in Refs. 7 and 8; however, several changes have been made since the system was originally installed. In general, the instrumentation output signals are connected to a pulse amplitude modulation (PAM) system and recorded on tape. The tape system is mounted

inside the BDU and controlled by an on/off switch on the co-pilots side of the cockpit. There are approximately 12 minutes of record time available which means that the recorder is turned on only at discrete intervals during the flight.

A photograph of the BDU-12 installed on the left inboard pylon of a F-111D is presented in Fig. 6. The peculiar looking radial strips on the front half of the BDU are Tempilaq® paint strips. Tempilaq paint changes phase from a solid to a liquid (melts) at a specified temperature. The paints consist of calibrated melting paint materials suspended in an inert carrier. The specific paint temperatures used in the photograph were 300, 250, 200, and 150°F. These paints are commonly used in wind tunnel testing to obtain heat transfer data (Ref. 9). The use of these paints in flight testing will be discussed in the next section.

Perhaps one of the more important results of this project has been the application of wind tunnel technology, such as the phase-change paint and the heat gages, to the aircraft/store compatibility field.

RESULTS AND DISCUSSION

To date only a limited amount of flight test data have been obtained and by far the most dramatic has been the data obtained using the phase change paint. These data are presented in Fig. 7. The most interesting aspects of these pictures is not the temperature level but the flow patterns which are clearly illustrated by the melted 150°F paint. These patterns correspond to local streamlines and are produced as the paint melts and the local shear forces cause the melted paint to flow. The paint melts when the wall temperature reaches the specified temperature (e.g., 150°F) which, of course, does not occur until the aircraft accelerates significantly above Mach 1 producing recovery temperatures greater than 150°F. Of particular interest are the flow disturbance patterns produced by the shock off the pylon, and by the sway braces. It is also important to note that the Mach number reached during this flight was 2.5. This clearly demonstrates that supersonic carriage of large stores can be accomplished with present-day aircraft. Surely, the "arbitrary restriction" of this capability should be avoided on the coming generation of aircraft if the technology is available to remove this restriction.

Illustrated in Fig. 8 is the difference between the Reynolds number level obtainable in the wind tunnel as compared to that of the full scale BDU at flight conditions. This Reynolds number difference shows the significance of the scaling relationship (equation 4). Also shown in Fig. 8 are the two test points which have currently been completed by the flight test program. Typical data are presented in Figs. 9 and 10. Figure 9 shows a limited amount of flight test data compared to the interference-free Spalding-Chi calculations. The relatively good agreement is considered fatuitous; however, this figure does illustrate the application of the correlation parameter, $St(Re_{\infty,x})^{0.17}$.

The temperature rise of the BDU which occurred during acceleration to Mach 2 is presented in Fig. 10. The temperature differential across the "skin thickness" of the BDU was negligible. Also shown are the ambient temperature and the calculated recovery temperature, T_r. It can be shown that

$$T_r \approx 0.96\ T_o$$

where T_o is the measured total temperature. The main conclusion from these data are that the BDU temperatures reached or excessed 178°F within the 4 minutes of sustained Mach 2 flight.

CONCLUDING REMARKS

Flight tests of an instrumented BDU-12 are being conducted at Edwards AFB on an F-111 aircraft. To date only a limited amount of data have been obtained; however, the following general comments can be made:

1. These tests have demonstrated that supersonic carriage of large stores can be accomplished with present-day aircraft up to Mach 2.5.

2. The application of wind tunnel technology to the aircraft/store compatibility field has been demonstrated.

3. The BDU temperatures reached or exceeded the temperature at which TNT melts (178°F) within the four minutes of sustained Mach 2 flight.

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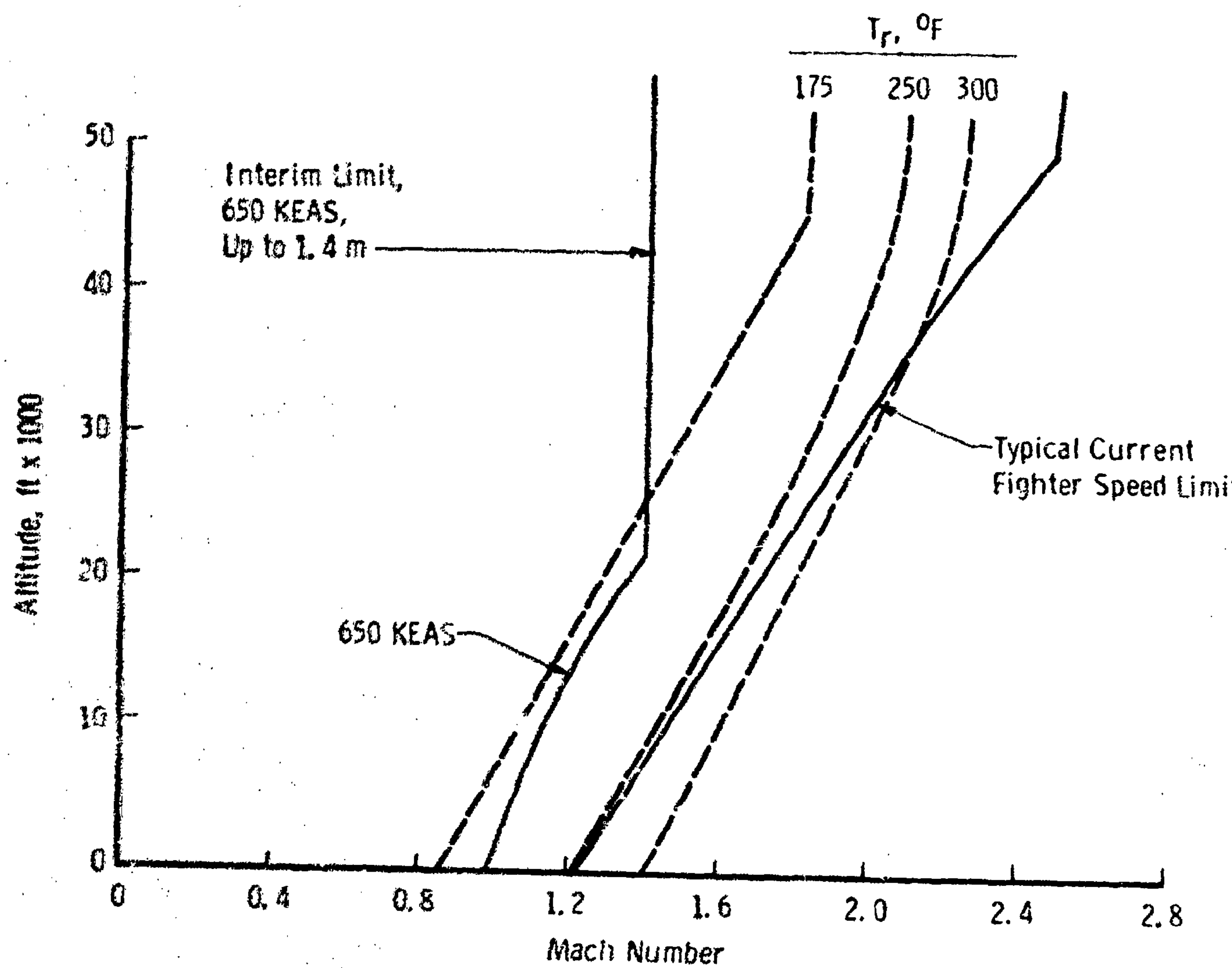

Fig. 1 Performance Envelope of Present-Day Aircraft

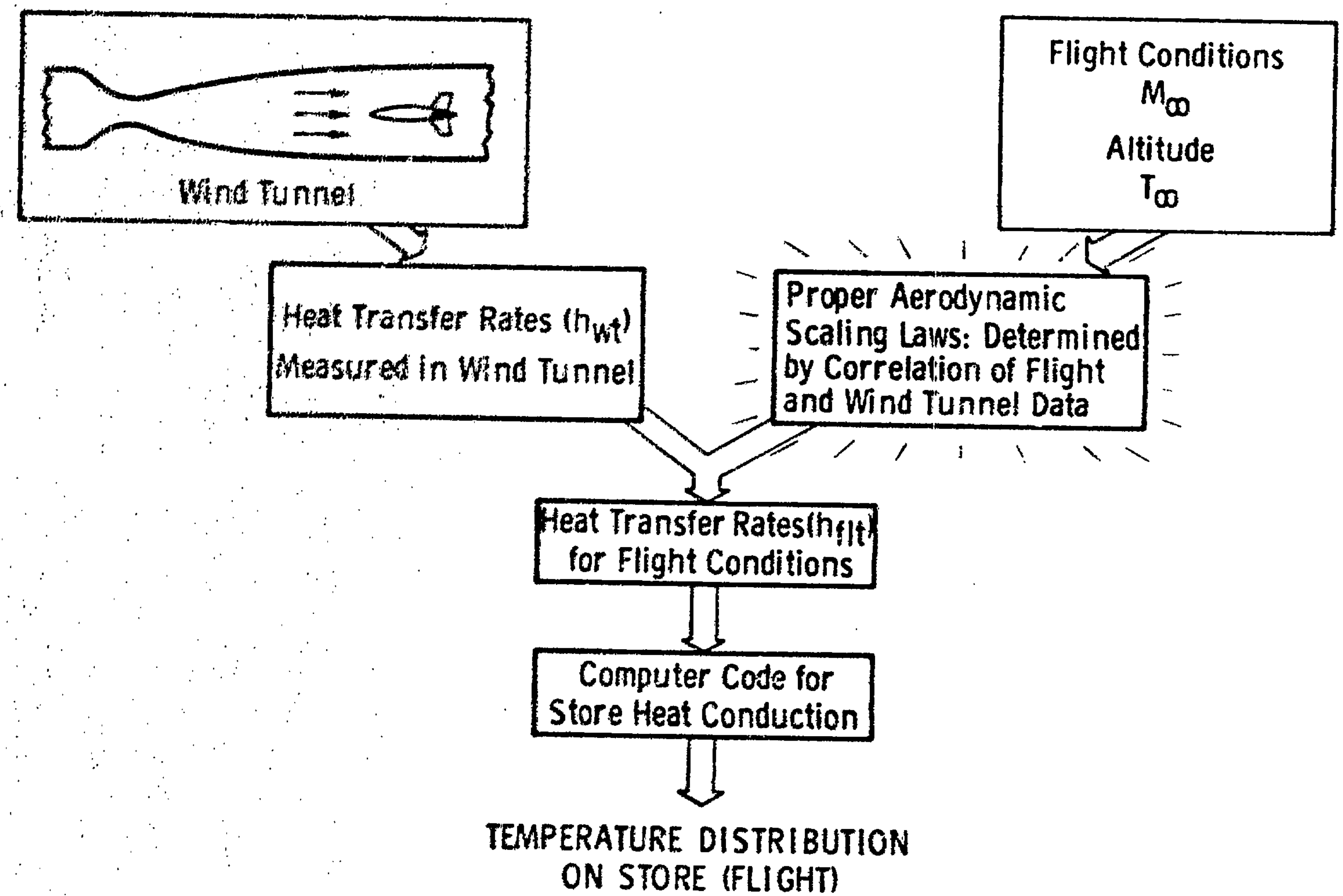

Fig. 2 Schematic Showing Extrapolation of Wind Tunnel Data to Flight Conditions

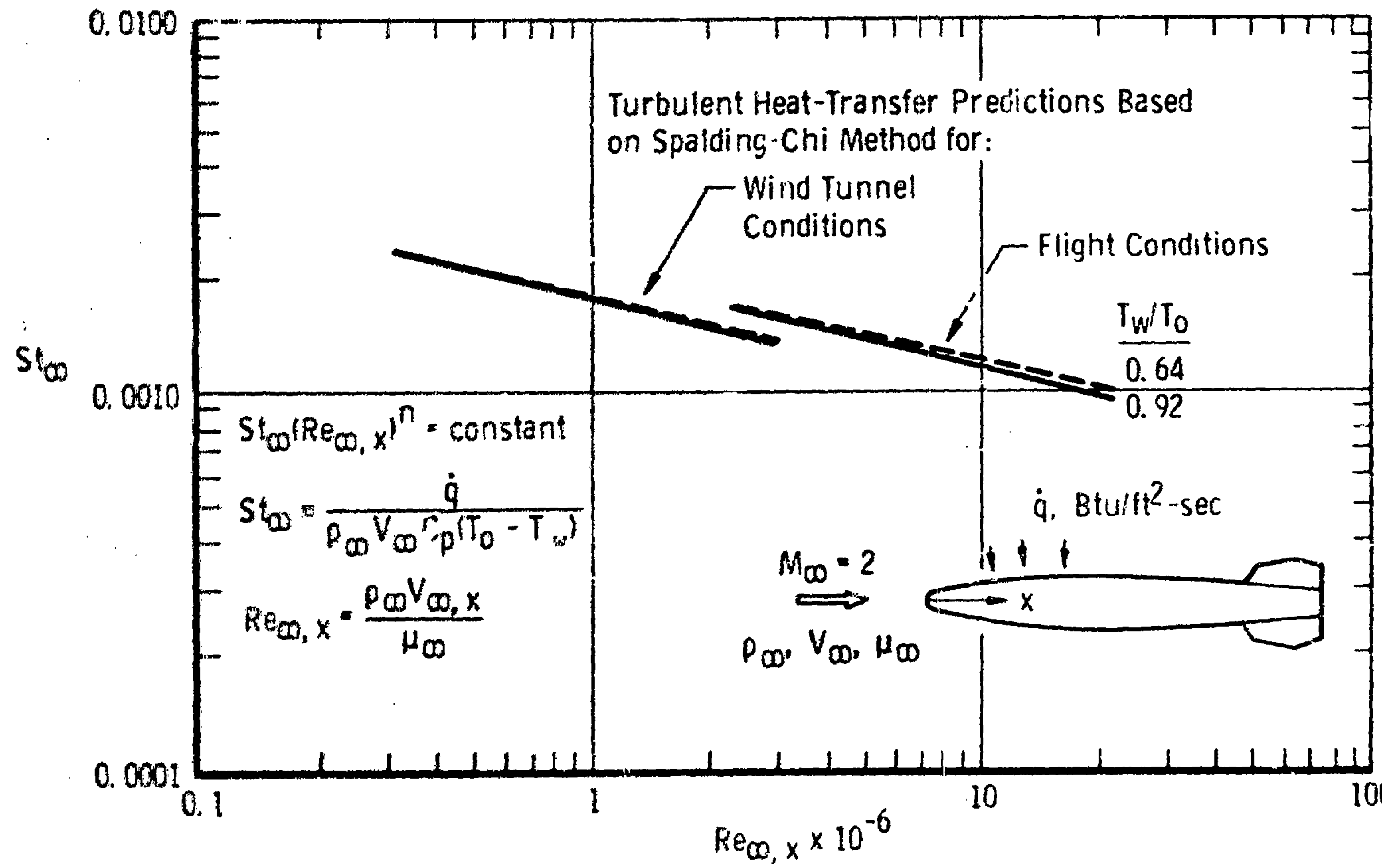

Fig. 3 Effect of Wall Temperature and Reynolds Number on Store Heating Rates

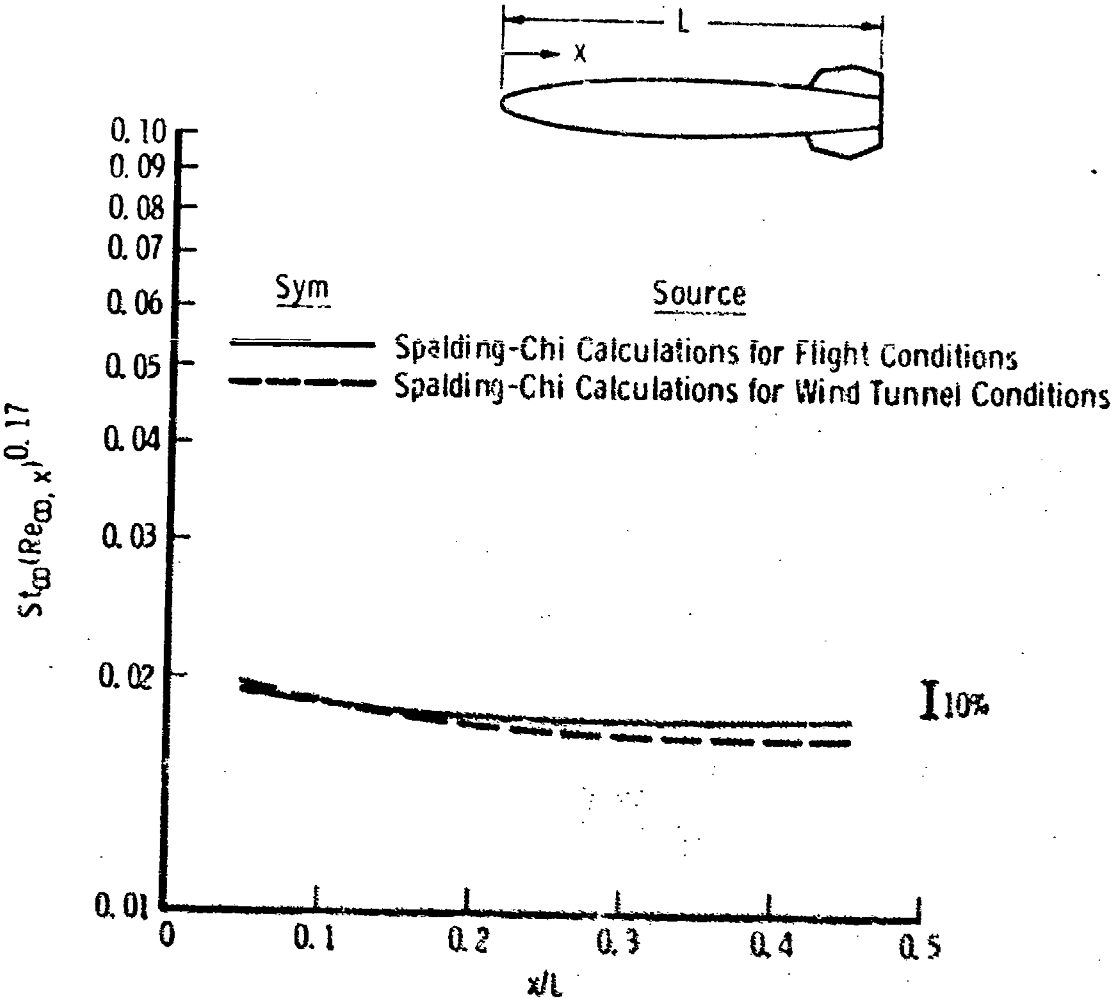

Fig. 4 Parameter Illustrating Extrapolation of Wind Tunnel Predictions to Flight Conditions

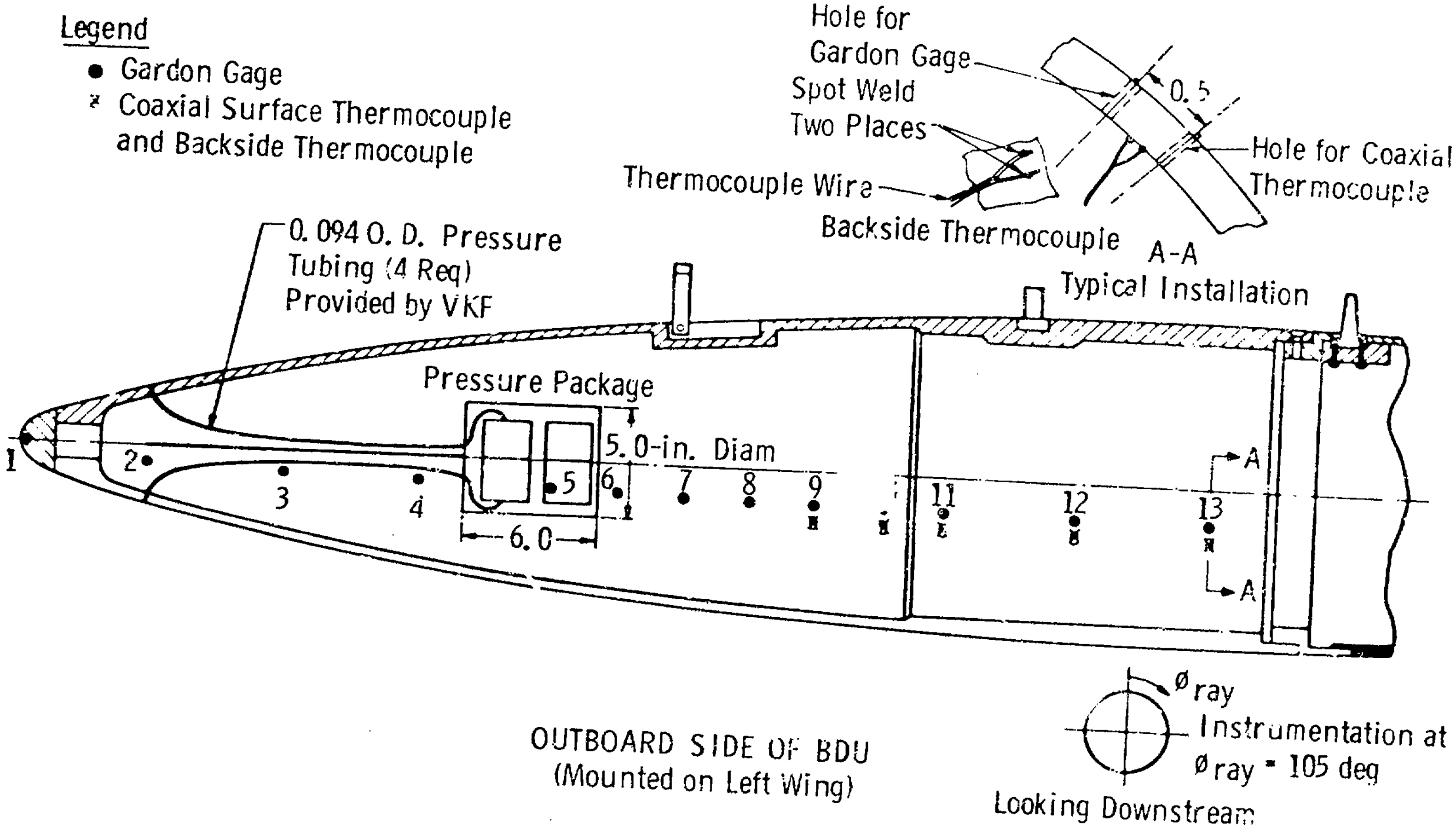

Fig. 5 VKF Instrumentation for BDU Aerodynamic Heating Test at Edwards AFB

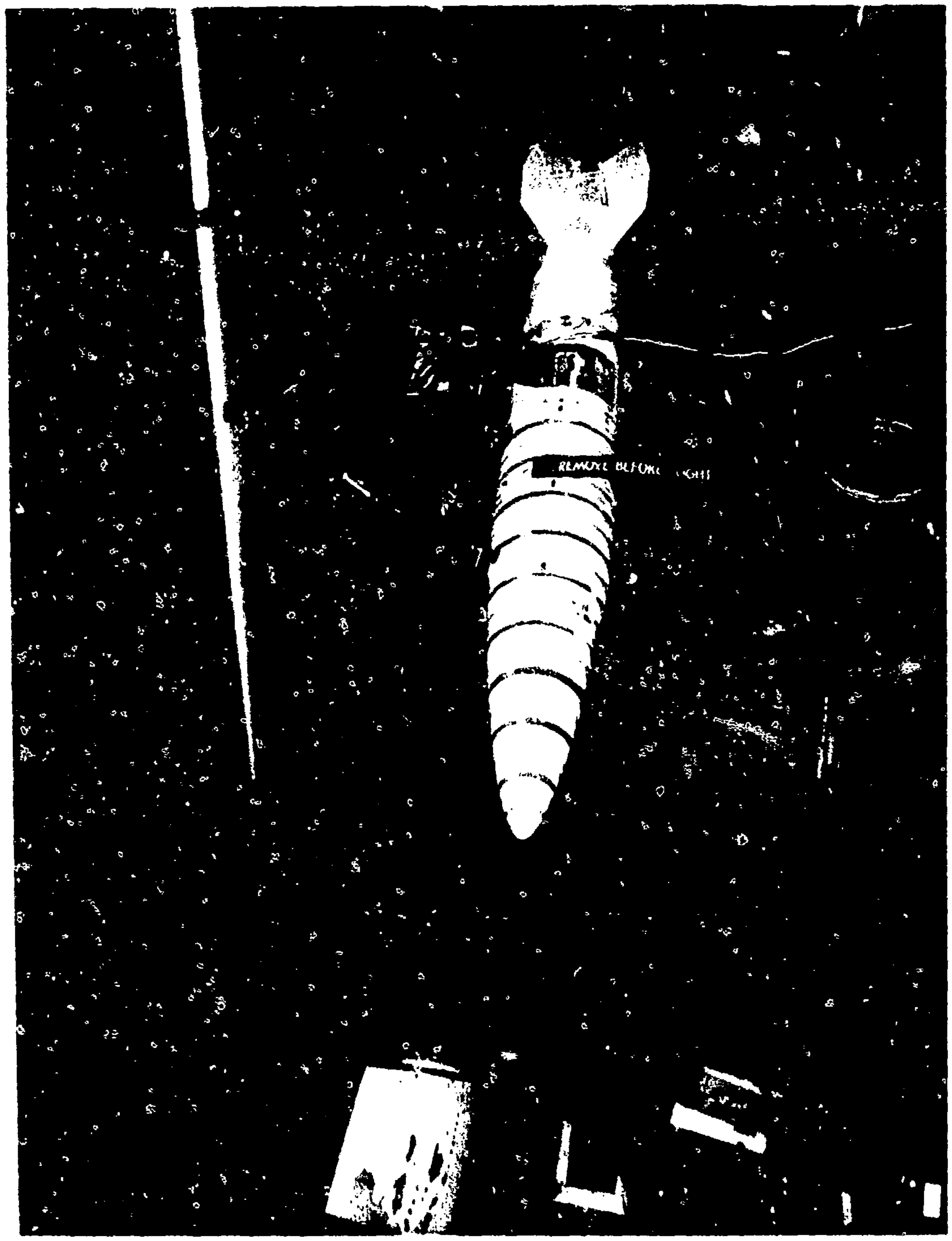

Fig. 6 Pre-Flight Photograph of BDU with Phase-Change Paint Applied

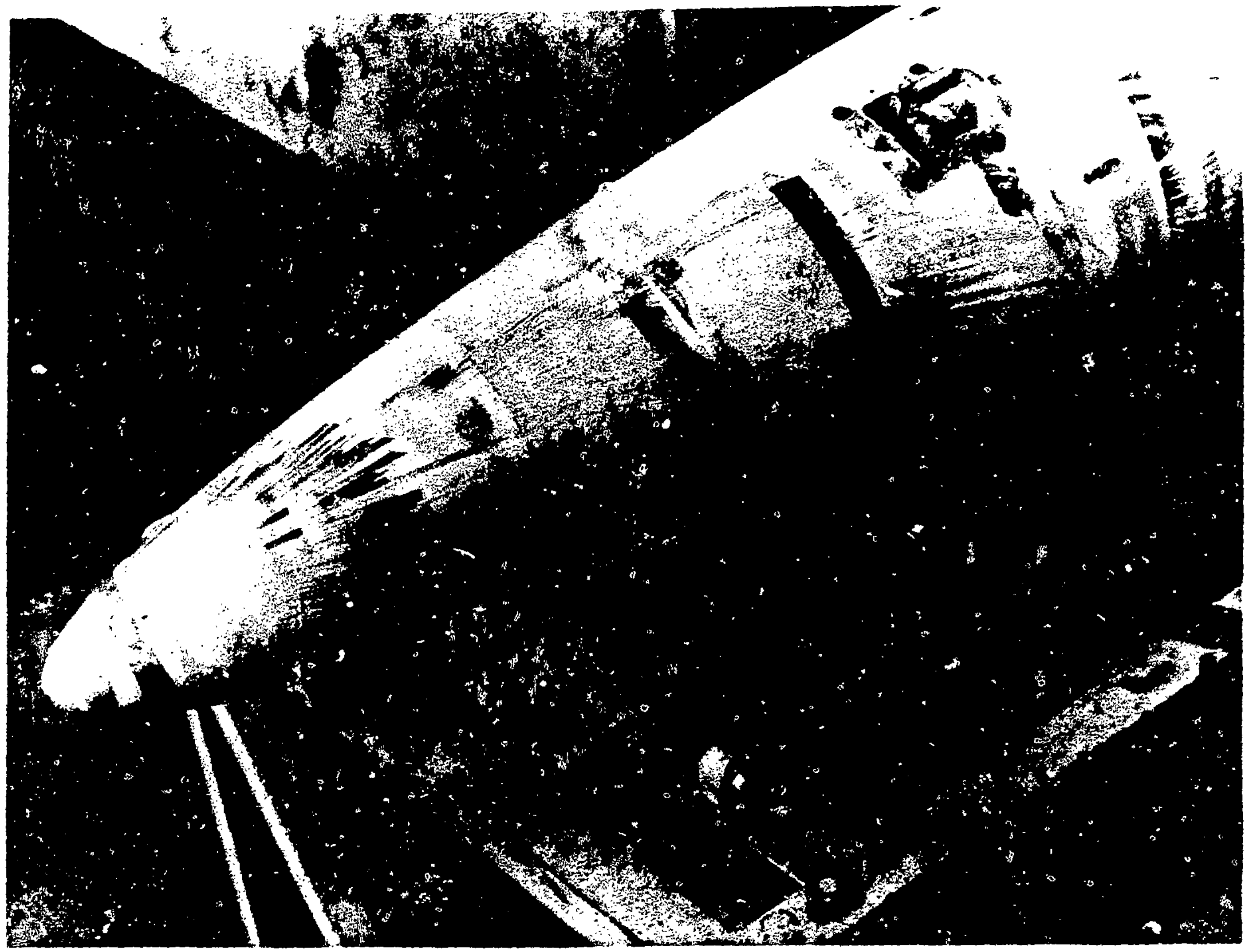

Fig. 7 Post-Flight Photograph of Phase-Change Paint after Mach 2.5 Flight

Fig. 7 Continued

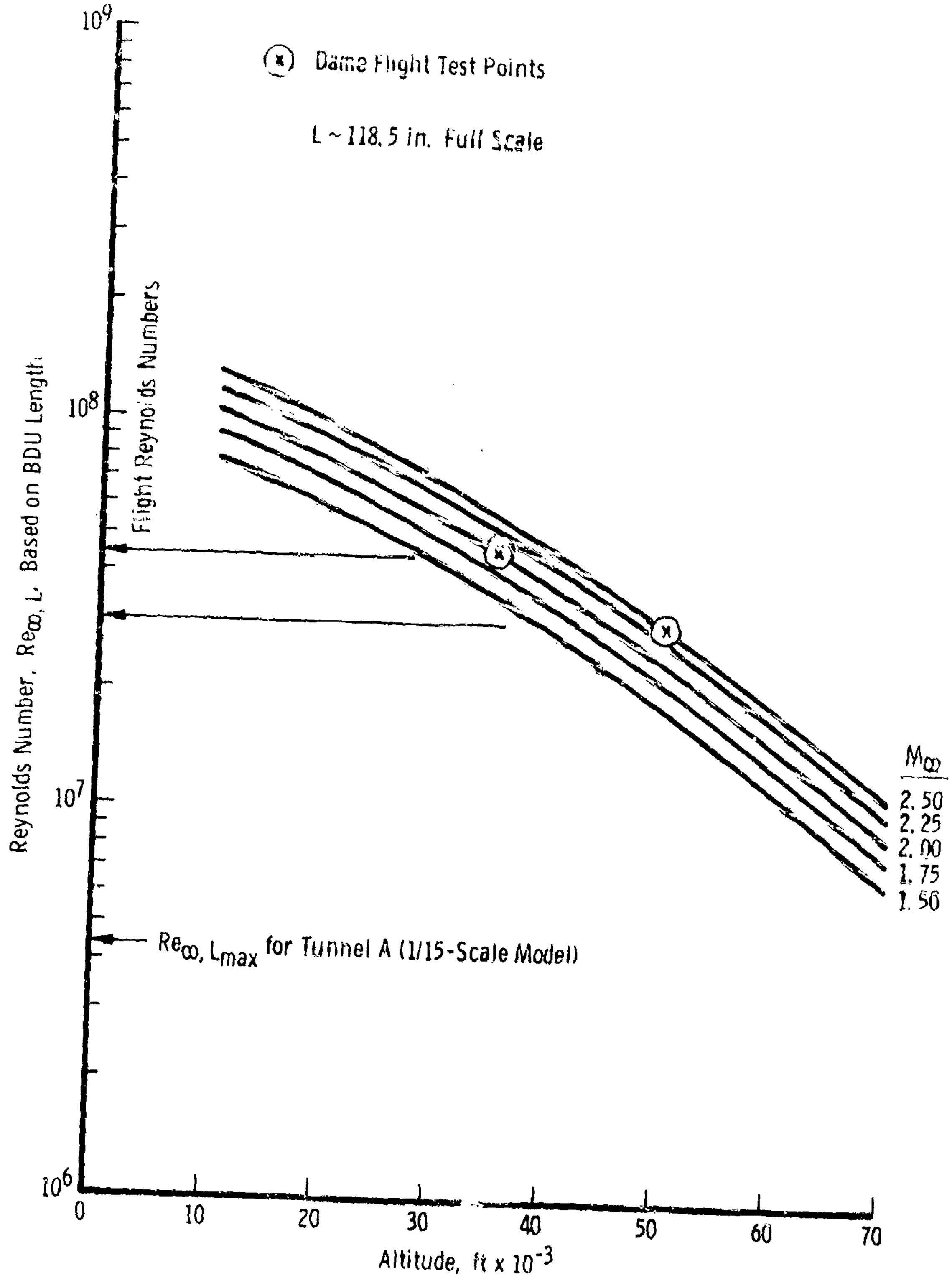

Fig. 8 Comparison of Wind Tunnel and Flight Test Reynolds Numbers

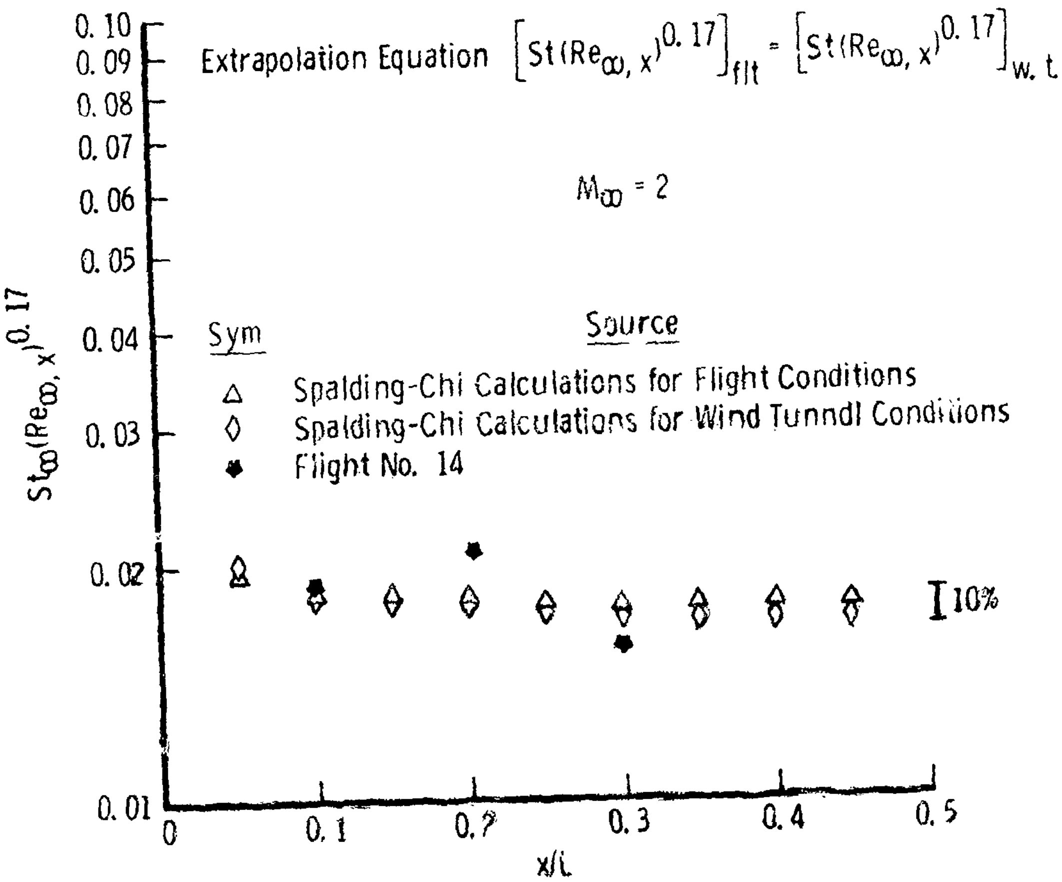

Fig. 9 Correlating Parameter for Flight and Wind Tunnel Data

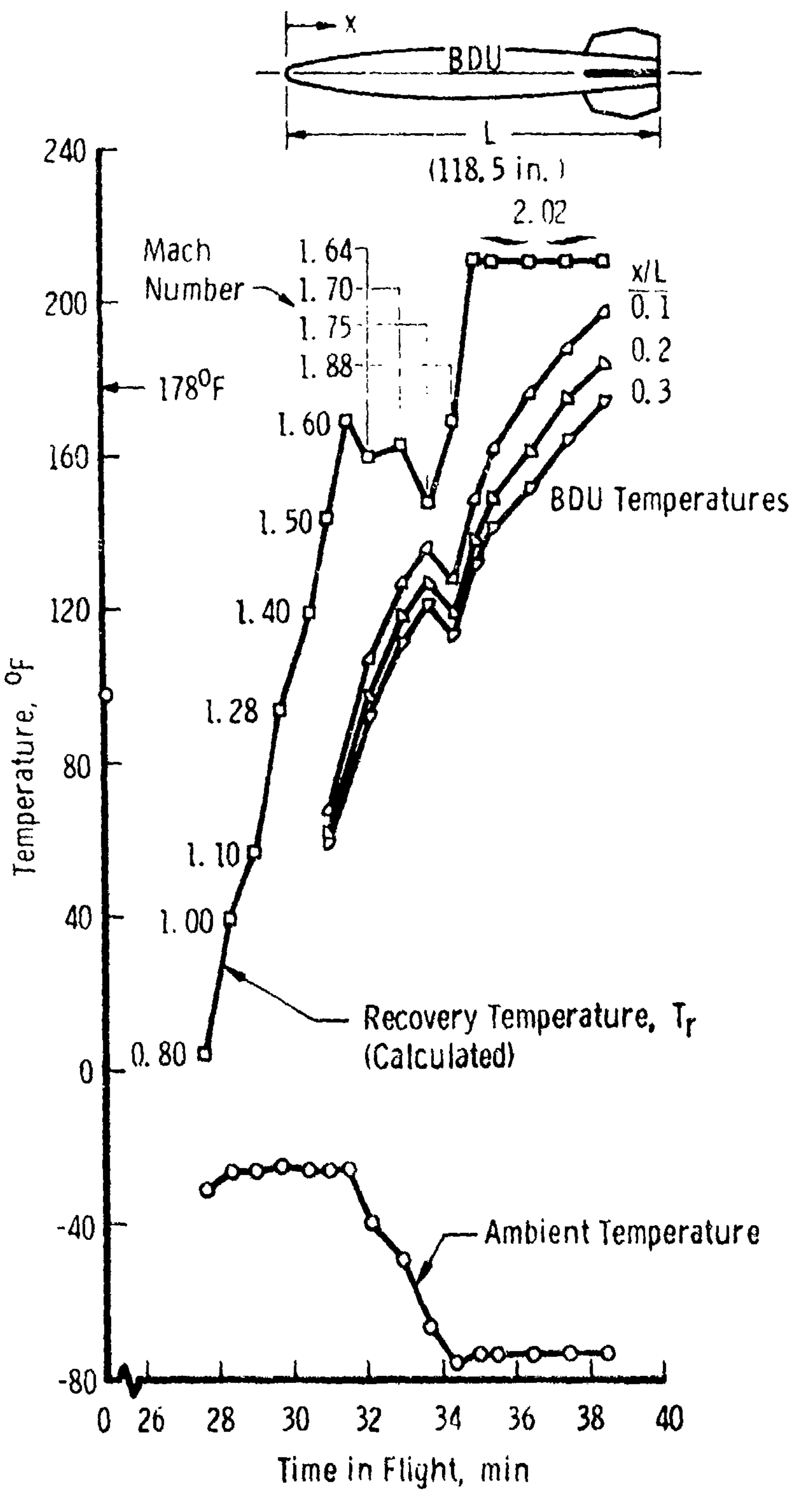

Fig. 10 Principal Results from Flight Test No. 14

AUTOBIOGRAPHY

R. K. MATTHEWS

Mr. Matthews has over 13 years experience as a project engineer in the Aerodynamics Projects Branch of the von Kármán Gas Dynamics Facility (VKF) of the Arnold Engineering Development Center (AEDC). In recent years he has been the principal investigator on research directed toward aircraft/store capability and has also conducted extensive aerodynamic heating tests on space shuttle configurations and published numerous reports and papers analyzing the results of these tests. He is a member of the AIAA and has experience in all fields of aerodynamic wind tunnel testing at both supersonic and hypersonic speeds. In 1967, he was awarded an M. S. degree from the University of Tennessee Space Institute. His undergraduate work was done at Parks College of St. Louis University, where he also received a commission in the Air Force. He served three years as an aircraft maintenance officer and has taught basic engineering courses at several colleges.

AUTOBIOGRAPHY

JAMES C. KEY, JR.

Major Key graduated from the University of Florida with a BME degree in 1963. He entered the USAF the same year and was assigned to ASD (AFSC) at Wright-Patterson AFB, Ohio, as a propulsion and power engineer. He was selected for graduate studies in aerospace engineering at the U. S. Air Force Institute of Technology, entering in 1967 and graduating in 1969 with an MSAE. He was then assigned to AFLC units at McClellan AFB, California (aircraft modification and design engineer) and Bangkok, Thailand (depot-level aeronautical engineering support to PACAF operational units).

He is now assigned to the Air Force Armament Laboratory (AFSC) at Eglin AFB, Florida, as a project engineer for Aircraft/Weapons Aerodynamic Heating.

EVOLUTION OF THE PAVE PENNY GUNFIRE

VIBRATION ENVIRONMENTAL QUALIFICATION

TESTS

(U)

(Article UNCLASSIFIED)

by

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ABSTRACT. (U) The PAVE PENNY Pod installation on the A-7D, located only 18 inches from the 20 mm M-61 gun, places it in a very intense vibration environment which results from the blast pressure fields generated by firing the gun.

Test level development is traced from predictions, to flight test measurements, to laboratory simulation.

When the pod was subjected to the predicted gunfire vibration simulated by discrete frequency sinusoidal components, severe damage to the pod resulted. The decision was made to measure in flight tests the vibration input to the pod at the attachment points. These data indicated a better test simulation could be obtained by superimposing four sinusoids, the fundamental fire rate and the first three harmonics, onto a broad-band random background. Although the pod performed well during flight tests, this laboratory simulation also produced pod damage. The final flight data included response measurements on the internal pod structure. These internal responses were used to establish response limits for the four sinusoids to complete the definition of the gunfire simulation laboratory test.

INTRODUCTION

The Air Force's Target Identification Set, Laser AN/AAS-35(V) (PAVE PENNY) is a miniaturized laser acquisition and tracking system. Designed for adaptation to a variety of existing and future aircraft, this advanced day/night system searches for, acquires, and tracks laser energy reflected from targets designated by airborne or ground-based observers. For complete fire control capability, the system can be integrated with aircraft avionics.

In the development stages of the PAVE PENNY Pod, the Air Force chose the A-7D to demonstrate the target acquisition capability of the pod. The PAVE PENNY Pod installation on the A-7D, located only 18 inches from the 20 mm M-61 gun, places it in a very intense vibration environment which results from the blast pressure fields generated by firing the gun. The location of the pod relative to the gun muzzle is shown in Figure 1. It was apparent that the Air Force had not considered these effects and had not planned on the utilization of the gun during the demonstration. The evolution of the laboratory qualification test representing the gunfire vibration environment is the subject of this paper. Test level development is traced from predictions, to flight test measurements, to laboratory simulation.

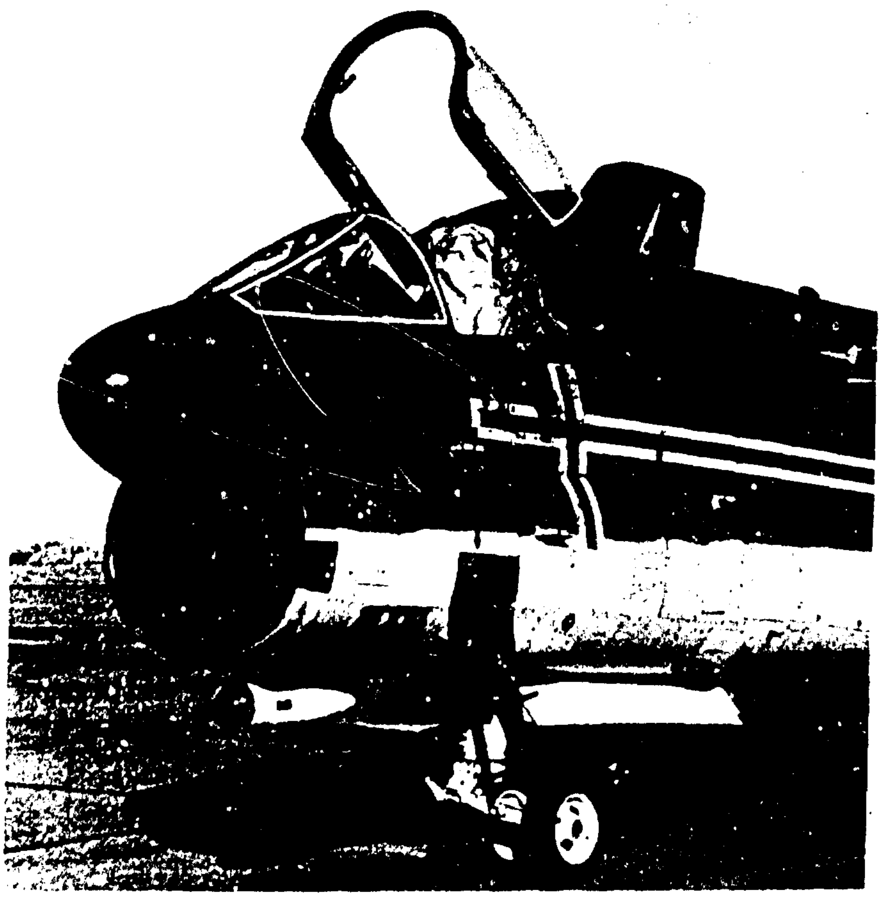

Figure 1. Left Quartering View of A-7D Airplane Nose Section with Pave Penny Pod Installed

If the pod was to be procured for this location on the A-7D, it was obvious that the gun would be utilized and the pod would be required to survive the intense environment generated by the blast. The intensity of the vibration environment was highlighted by the LTV environmental qualification specification test levels for equipments on the aircraft located within four feet of the gun. When subjected to these levels, failures were experienced by the pod. These early failures and Air Force predictions of the vibration environment prompted the Air Force to complete the flight development program prior to firing the guns or subjecting the development pod to a gunfire vibration environment in the lab. After the concept of target identification was successfully completed, the guns were fired in flight. Failures resulted in the pod. As a result of the flight failures and much discussion, the decision was made to conduct in-flight tests and measure the vibration input to the pod at the attachment points. These data indicated a better test simulation could be obtained by superimposing four sinusoids, the fundamental fire rate for the first three harmonics, onto a broad-band random background. This was consistent with the environment and tests promulgated by the Air Force. Although the pod performed well during flight tests, this laboratory simulation also produced pod damage. The final flight data included response measurements on internal pod structure. These internal responses were used to establish response limits for the four sinusoids to complete the definition of the gunfire simulation laboratory test.

GUNFIRE ENVIRONMENT

LTV GUNFIRE VIBRATION TEST

The A-7D gunfire test was empirically derived from gunfire vibration measurements on the A-7D aircraft structure. The test levels depend on distance from the muzzle and are entirely periodic vibration composed of the discrete frequency sinusoidal components at the fundamental and each harmonic of the gunfire rate up to 2000 Hz. This environment is illustrated in Figure 2 for the high fire rate. The peak amplitude of the fundamental was 10.6g, the peak of the first three harmonics was 21g, and the peak of the higher harmonics decreased to less than 3g at 2000 Hz. The environment excitation was generated using a pulse generator to produce a periodic pulse train having a repetition rate equal to the gunfire rate. The output of the pulse generator was applied to the input of the vibration equalization system where the amplitude of each component in the spectrum was adjusted to the allowable tolerance of the desired test level. The overall vibration level was measured after passing the control accelerometer output through a 2500 Hz low pass filter. Attempts to impose this periodic gunfire vibration testing resulted in severe damage to the pod.

FLIGHT TEST PROGRAM

It was then decided to measure the gunfire vibration environment via an A-7D flight measurement program. Three sets of data were obtained in the program. The initial set of data was obtained at Eglin AFB in November 1973. Accelerometers were located on the fore and aft pod adapter plate to

measure the input to the pod at its mounting points. Accelerometer locations are illustrated in Figure 3. The primary conclusion from these data and an industry survey of gunfire environments and testing was that the gunfire vibration environment could best be simulated in the laboratory by superimposing four sinusoids, the fundamental firing rate and the first three harmonics, onto a 300-2000 Hz broad-band random vibration. The resulting recommended environmental definition for the vertical direction high-fire rate is shown in Figure 4. The overall grms for this spectrum is 30.3 as compared to the predicted environment of 36 grms.

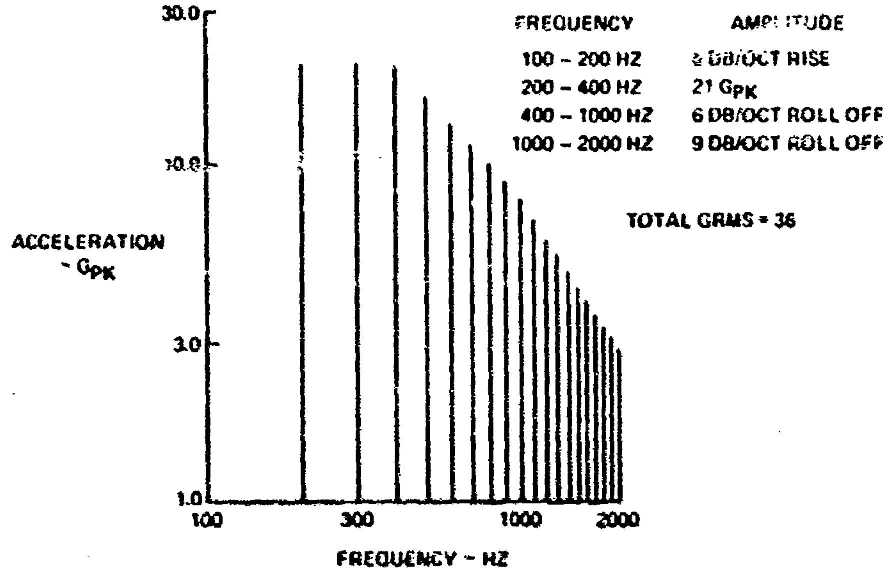

Figure 2. Gunfire Vibration Environment (High Fire Rate)

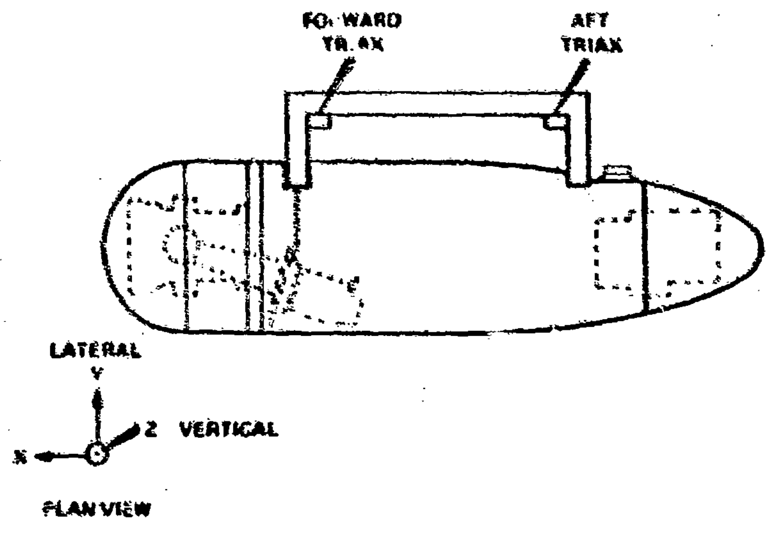

Figure 3. First Flight Test Accelerometer Locations

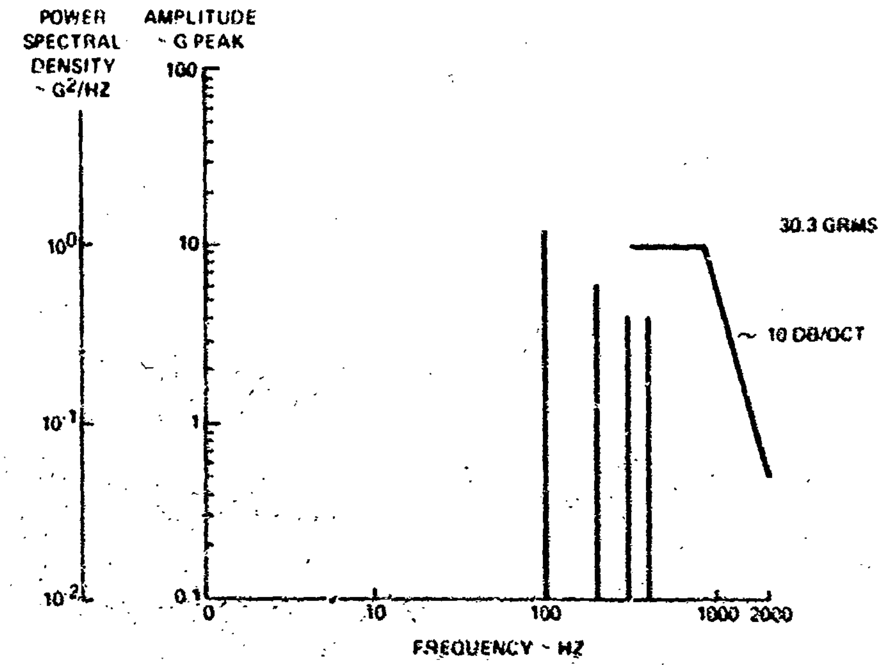

Figure 4. Pave Penny Recommended Gunfire Specification (High Firing Rate)

A second set of data was obtained from a series of flights conducted in February and March 1974. Accelerometers were mounted in the same position as the previous test, on the fore and aft adapter plate. These data indicated that the levels established from the initial data were too low in both the sinusoidal and random portions. The sinusoid amplitudes were, on the average, a factor of two higher and the random roll-off was only -3 dB/oct instead of -10 dB/oct.

The third set of data, which is considered to be the most valid in the development of a qualification test for the PAVE PENNY Pod in its present location on the A-7D, was obtained on 27 March 1974. These data were obtained with six accelerometers mounted inside the pod. Accelerometers were located in the gimbal area and on the fore and aft bulkheads as illustrated in Figure 5. Gimbal responses were measured in the lateral and longitudinal directions, lateral responses were measured on the bottom of the forward bulkhead, vertical responses were measured on the bottom of the aft bulkhead, and vertical and lateral responses were measured on the top of the forward bulkhead near the attachment points.

With the above data in hand, and the fact that the pod performed well in flight but not during vibration tests, the decision was made to conduct a response-limited qualification test to better simulate the in-flight environment in the vicinity of the most sensitive equipment. Inputs were defined at the pod mounting points and response limits were established from the flight data obtained on the bottom of the fore and aft bulkheads. The inputs and limits for the fundamental (100 Hz) and first three harmonics

are defined in Table I. Limits apply only to the sinusoidal components. In recognition of variations in gunfire rates, the harmonics are varied by ±15 percent about the nominal firing rates. The inputs are notched in the vicinity of the gimbal resonant frequency unless the resonance is within 5 percent of the nominal firing rate.

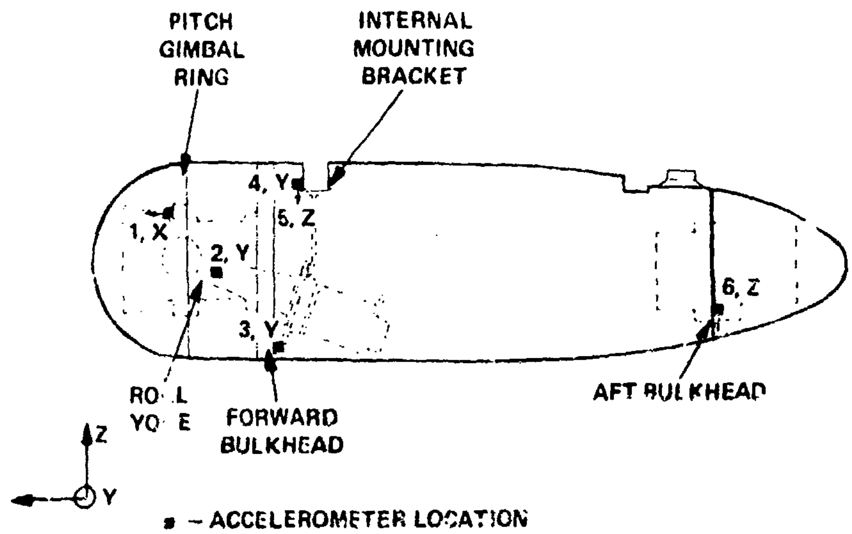

Figure 5. Accelerometer Locations

TABLE I

Test Levels

SINUSOIDAL:

FREQUENCY (HZ)	LATERAL (±G_{PK}) INPUT	LATERAL (±G_{PK}) LIMIT FORWARD BULKHEAD	VERTICAL (±G_{PK}) INPUT	VERTICAL (±G_{PK}) LIMIT AFT BULKHEAD	LONGITUDINAL (±G_{PK}) INPUT	LONGITUDINAL (±G_{PK}) NO LIMIT
100	6	17	9	9	4	
200	10	18	10	10	4	
300	17	42	25	25	5	
400	8	24	4	15	3	

RANDOM:

FREQUENCY (HZ)	PSD VERTICAL AND LATERAL	PSD LONGITUDINAL
300-1000	1 G^2/HZ	0.5 G^2/HZ
1000-2000	-3 DB/OCTAVE	-6 DB/OCTAVE

DURATION:

25 MINUTES/AXIS
THE LIMITS PERTAIN ONLY TO THE SINUSOIDAL PORTION.

LAB SIMULATION

TEST SETUP

Simulation of the response limited gunfire environment requires considerable electronics because the sinusoids must be generated and the response of each sinusoid must be monitored. A flow chart illustrating the technique used to generate and limit the sinusoids is shown in Figure 6. Sinusoids are generated by the harmonic generator, then amplified and fed into bandpass filters, one for each of the four harmonics. The output of each filter was fed into a peak g detector which had been set previously to trip and shut down the shaker if the filtered acceleration level exceeded the response limit for its frequency.

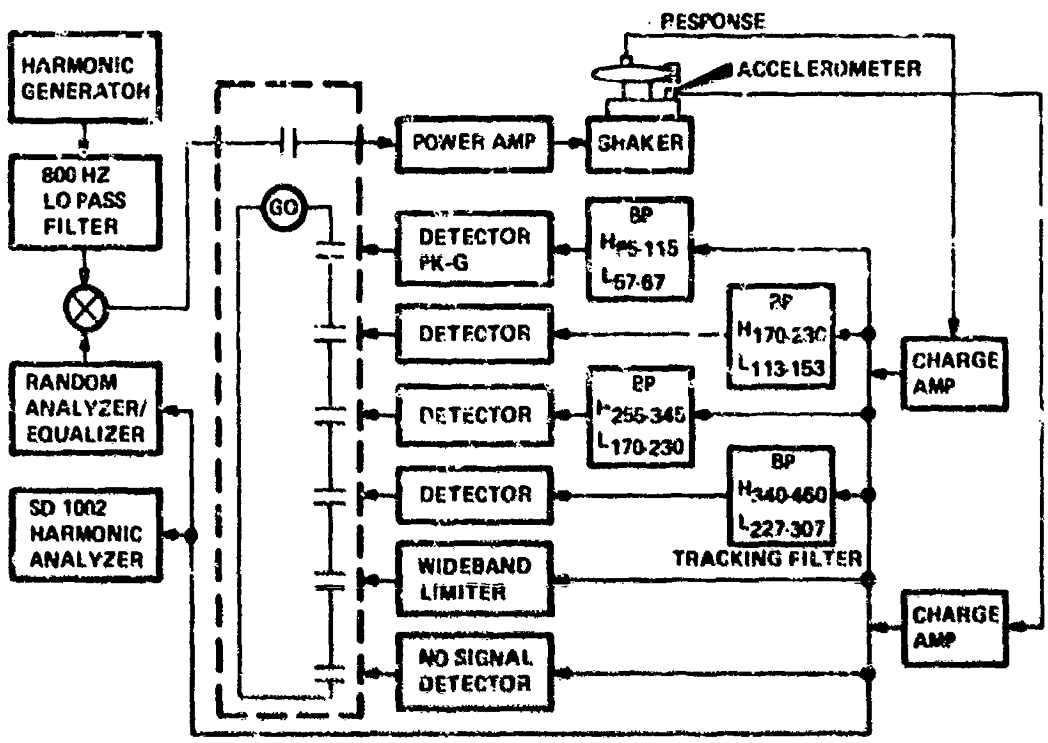

Figure 6. Aircraft Gunfire Vibration Control and Safety Interlock

LIMIT SETTING

Considerable difficulty was encountered in setting the detector circuitry so that it would trip at the desired level. The presence of random vibration introduced enough additional response to invalidate trip levels set under pure harmonic excitation. This problem was overcome by increasing the detector time constant to 0.9 sec and resetting the time levels with random vibration present. Final trip levels were set with the instrumentation installed on the pod (initial settings were made with the instruments

mounted on the bare fixture). It was also necessary to set limits 3 dB above the desired trip level to allow margin to run the test at the desired levels.

An additional difficulty was imposed by the requirement to sweep ±15 percent about the nominal frequency while keeping the inputs and responses within the desired levels. Trip levels were set at the frequency within the ±15 percent band allowing maximum amplification.

TEST RESULTS

An R&D PAVE PENNY (S/N 001) was exposed to two series of tests during August and September of 1974. The first utilized an electrically functional pod and was run at input excitation levels matching those measured in flight. This resulted in internal response levels considerably in excess of the flight data. The second series of tests was conducted utilizing the internal response levels as limiters and adjusting the input excitation as close as possible to the flight test data without exceeding the response limits.

A chart comparing desired inputs and limits to values obtained in the second of these tests is presented in Table II. The test levels were established by increasing the input until the response limit was reached or until the desired input level was reached. Data presented in Table II are the maximum values recorded in the tests as the fire rate was swept through a ±15 percent variation of fire rate. Beside each test value in Table II, the fundamental gunfire frequency at which the maximum occurred is recorded. The effects of response limited inputs are illustrated in Table II in the vertical axis - high fire rate data. In this test the first three frequencies are response limited. Random vibration levels are low due to mechanical shaker limitations.

TABLE II

Pave Penny Pod S/N 001 Vibration Test Data Summary
Reflecting Inputs and Control Limits

		VERTICAL AXIS								LATERAL AXIS							
		SINUSOIDAL (PEAK) VALUES						OVERALL INPUT (GRMS)		SINUSOIDAL (PEAK) VALUES						OVERALL INPUT (GRMS)	
		FORWARD MOUNTING RING LOCATION FIXTURE INPUT			BOTTOM AFT BULKHEAD LOCATION LIMIT					FORWARD MOUNTING RING LOCATION FIXTURE INPUT			BOTTOM FORWARD BULKHEAD LOCATION LIMIT				
GUNFIRE RATE	FREQ (F) (HZ)	SPEC	TEST	GUNFIRE FREQ (HZ)	TEST PLAN	ACTUAL TEST	GUNFIRE FREQ (HZ)	SPEC	TEST	SPEC	TEST	GUNFIRE FREQ (HZ)	TEST PLAN	ACTUAL TEST	GUNFIRE FREQ (HZ)	SPEC	TEST
HIGH (100 HZ)	100	9	7	100	9	8.5	85	4.25	13.4	8	8	100	17	8.6	100	40.0	30.0
	200	10	7	100	10	11	115			10	7	115	16	8.5	100		
	300	35	11	85	25	24	115			17	17	85	42	17	85		
	400	4	*	–	15	*	–			8	8	100	24	8	85		
LOW (67 HZ)	67	7	7	67	9	6	67	4.07	22.0	5	5	67	17	11	77	30.0	14.0
	134	5	6	77	10	4.5	77			6	7	57	16	16	77		
	201	30	30	57	25	22	57			46	6	67	42	25	67		
	268	2.2	3	57	15	8.5	77			6.0	7	57	30	11	57		

*DATA IN THE NOISE LEVEL
NOTCHED OUT BETWEEN [illegible] AND 115 HZ IN VERTICAL AXIS AND BETWEEN 80 AND 95 HZ IN LATERAL AXIS

Data presented in Table III compares flight test responses to laboratory test responses. Results are included for both vertical and lateral axes and compare data at locations common to both flight and test. Instrumented locations at the mounting foot and bulkhead were the basis for the test inputs and limit responses, therefore, there should be good correlation and there is at the mounting foot and aft bulkhead. Correlation at the forward bulkhead and roll yoke location was not good. This could result from testing Pod /N 001 whose structural condition has deteriorated due to a history of previous testing.

TABLE III

Test Level Comparison

	FREQUENCY (HZ)	PULSE TEST: LATERAL AND VERTICAL (G_{PK})	RESPONSE LIMITED SINUSOIDS ON RANDOM BACKGROUND: LATERAL (G_{PK})	RESPONSE LIMITED SINUSOIDS ON RANDOM BACKGROUND: VERTICAL (G_{PK})
HIGH FIRE RATE	100	10.6	8	7
	200	21	2	7
	300	21	17	11
	400	21	8	*
LOW FIRE RATE	67	10.6	5	7
	134	21	7	8
	201	21	5	20
	268	21	7	3

*DATA IN THE NOISE LEVEL

The reduction in the low frequency input is summarized in Table III, where the final test level is compared to the early pulse test predictions for the first four frequencies. In each case the final input is lower than that specified for the pulse test. The final overall grms, however, is comparable to the early prediction.

SUMMARY

The above discussion summarizes the evolution of the PAVE PENNY Gunfire Vibration Environment Qualification Tests and the test results on the R&D pod demonstrates that a meaningful response limited gunfire vibration test can be conducted in the laboratory.

The vibration input, consisting of four sinusoids superimposed over a random background, simulated the gunfire vibration environment seen by the PAVE PENNY Pod when carried by the A-7D aircraft. The sinusoids were at the basic gunfire frequency for both high and low rates of fire and their harmonics. The high gunfire rate sinusoids are 100, 200, 300, and 400 Hz and the low gunfire rate sinusoids are 67, 134, 201, and 268 Hz. The sinusoids were swept, synchronously over ±15 percent bandwidth of the gunfire rates and their harmonics beginning at the low end and ending at the high

limit. Accelerometers were used for both control input to the pod in both axes and for response limiting in the vertical and lateral axis.

RECOMMENDATION

Tests based on inputs only can produce internal responses in excess of those experienced in flight; therefore, when aircraft stores are exposed to severe gunfire environment as is PAVE PENNY, it is recommended that response limited qualification tests be defined based on in-flight measurements of internal pod responses.

It should be pointed out that the Air Force has the only vibration prediction technique to date. This prediction along with the test requirements are contained in the new MIL-STD-810C, Method 519. Pod response limit is unique to the PAVE PENNY Pod for this type of test. Response limiting tests are, however, contained in 810C and recognized as the acceptable test method for stores when vibration tested for normal environments.

AUTOBIOGRAPHY

Ward D. Robertson received his B.S. in Mechanical Engineering from the University of Alabama in 1965 and his M.E. in Mechanical Engineering from the University of Florida in 1969. He has been employed at Martin Marietta, Orlando Division, since 1965, working on Advanced Ballistic Missile Defense and Tactical Weapon System programs. Though his primary background is dynamic analysis of structures, he has considerable experience in the analysis of vibration and shock data obtained in flight tests, the preparation of test specifications based on flight data, and the laboratory simulation of the flight environments.

Mr. Robertson co-authored a paper titled "Dynamic Modeling of Nonlinear Couplings" which was published in the Shock and Vibration Bulletin.

John H. Wafford received his B.S. in Physics in 1961 from the University of Louisville. He has been in the Dynamics Branch Systems Engineering for 15 years; first specializing in the area of acoustics. Presently, Vibration and Acoustics Group Leader in the Airframe Directorate, Aeronautical Systems Division, W-PAFB, Ohio.

Mr. Wafford has written two technical reports: "Ground Acoustical Survey of the R8-57F Airplane with TF-33-P-11A Engine," ASD Technical Report SEG-TR-67-26, October 1967. "Guidelines for Establishing Interior Noise Level Criteria for Air Force Aircraft," ASD Technical Report SEG-TR-67-57.

Mr. Wafford co-authored a paper titled "Aircraft Equipment Random Vibration Test Criteria Based on Vibration Induced by Jet and Fan Engine Exhaust Noise," presented at the 43rd Shock and Vibration Symposium, Shock and Vibration Bulletin, October 1973.